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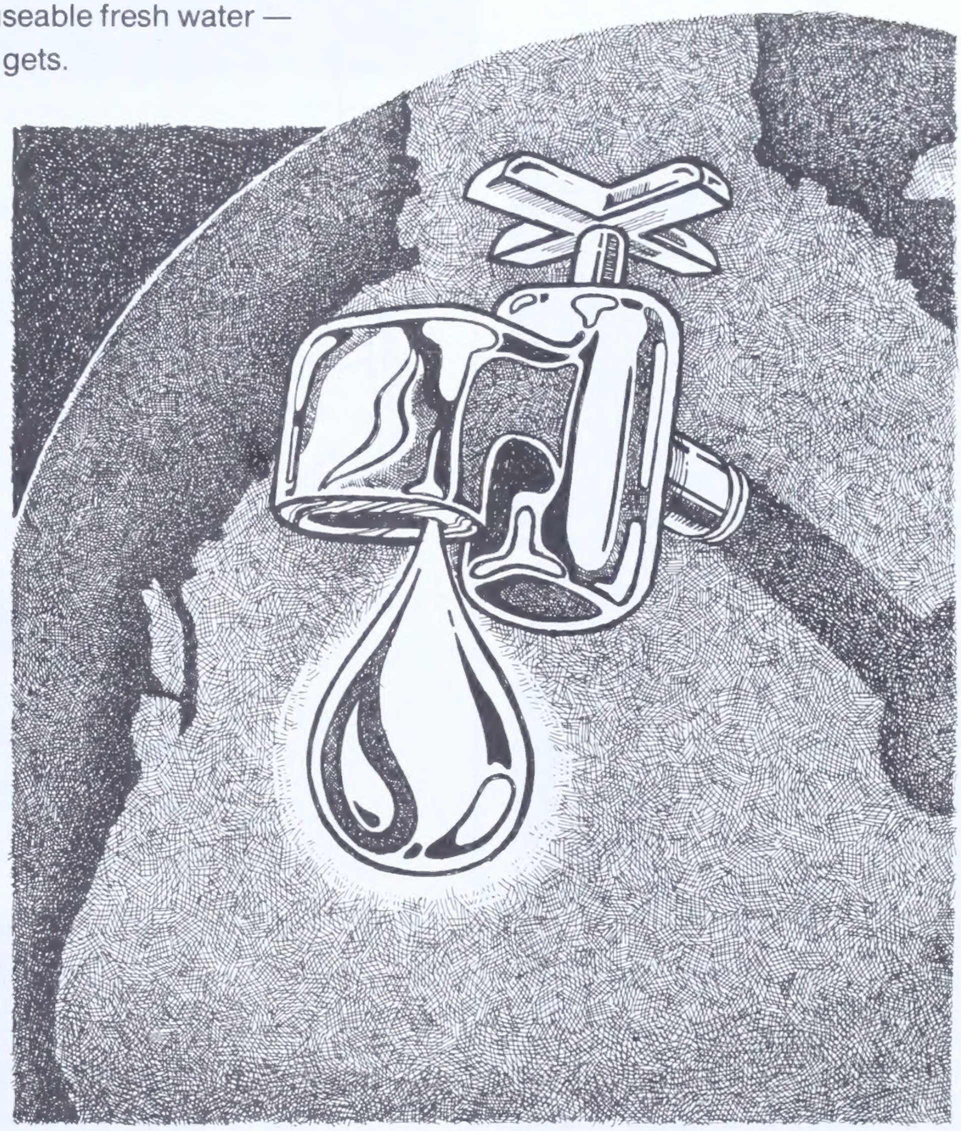
Groundwater — The Hidden Link

It accounts for most of the world's useable fresh water — and deserves more attention than it gets.



Literature for the layman on the subject of groundwater sometimes describes, then dispels, the illusion that it sits in lakes in vast underground caverns, or flows in rivers mysteriously under foot.

It does neither. But the reality is hardly less awesome. With few exceptions, the "rivers" are rivers of droplets, creeping (sometimes imperceptibly, unimaginably slowly) through the gaps between rocks, or the tiny pores between grains of sand.

Some groundwater never moves far from air and light; some inches deep into warm regions far below the earth's surface.

The stately rhythms of groundwater flow are a link in the even more majestic journey of all the waters of the earth as they circulate endlessly between ocean, atmosphere and land.

And though the groundwater link is largely hidden, it is highly significant: the sum of all those creeping droplets accounts for about two-thirds of the world's freshwater resources, and about 95 percent of the useable supplies (minus icecaps and glaciers).

As such, it is a vital resource, and one that in many parts of the world is heavily exploited. But it is much more than an exploitable resource: it has a role in landscape formation; in the migration and accumulation of minerals; even, perhaps, in the occurrence of earthquakes. As with all resource use, there are dangers in considering it in isolation from the natural systems of which it is a part.

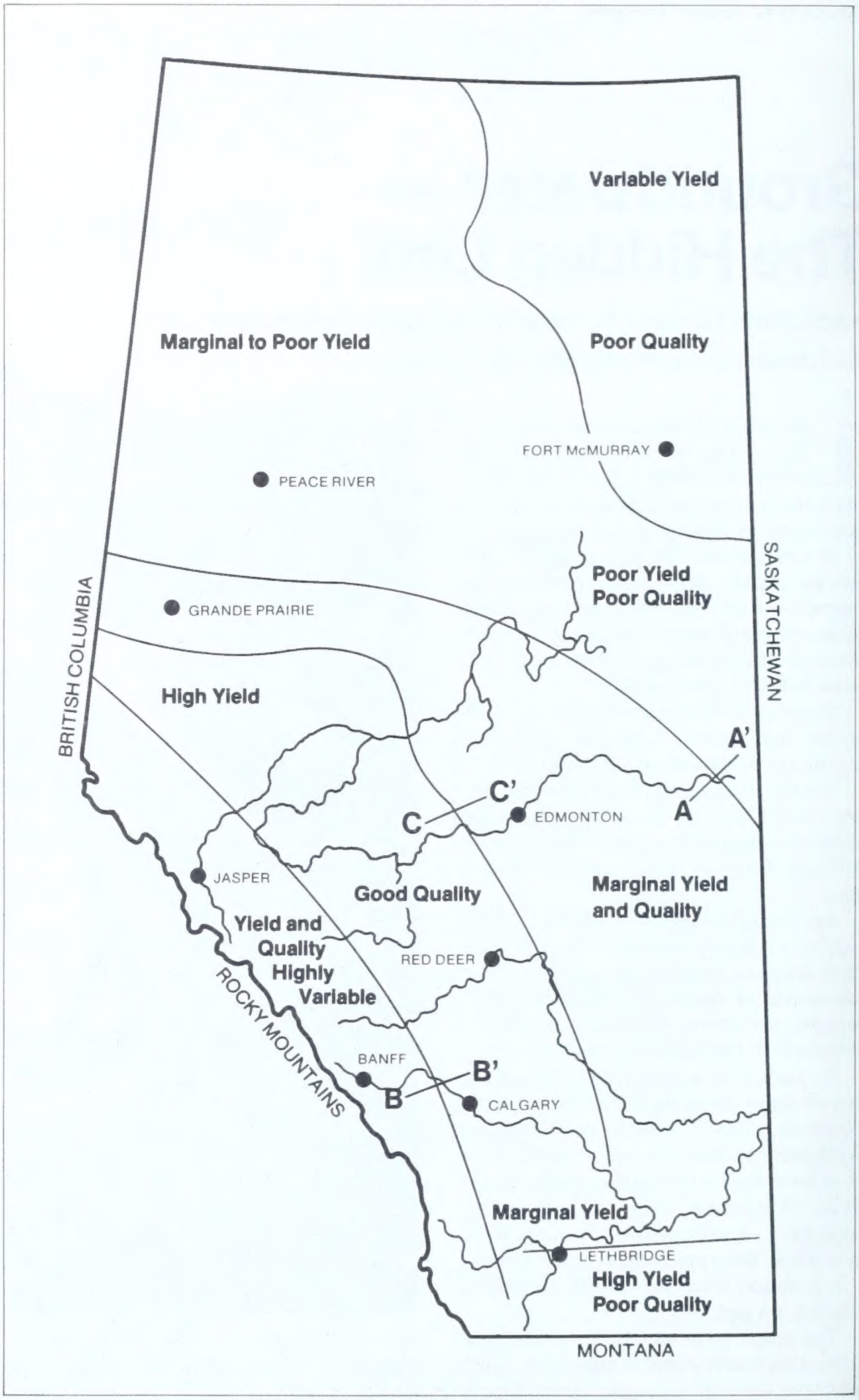
The origin of groundwater is precipitation, either from rainfall or snowmelt, which infiltrates through an upper zone of aeration to the water-saturated zone below. In the upper zone, water shares the space between soil grains with air, and makes up the reservoir of soil moisture on which plant life depends. Only a tiny proportion penetrates to the zone of saturation, bounded by the water table. Here water occupies all the spaces between soil grains and is able to move — albeit slowly. Direction of flow is determined by a complex set of factors, including water table configuration and geology, but is generally from upland areas to lower areas such as stream valleys or lake basins. At discharge points like these (or in springs, sloughs and other surface phenomena) water leaves the groundwater system.

Several factors determine the volume and rate of groundwater flow between its entry to the system at recharge points, and the points of discharge. Most important are *stratigraphy* — the order and relative position of geological strata of the earth's crust; *lithology* — the mineral composition, grain size and degree of packing of the material in a geological formation; and *structure* — the cleavages, fractures, folds and faults in the strata.

Certain formations, for example sand and gravel, are more porous than, say, a formation of fine clay. In very general terms (and with some exceptions) the more porous a formation, the greater its permeability and its ability to transmit water.

A saturated permeable geologic unit that can transmit significant quantities of water to a well is an *aquifer*. Wells in an aquifer introduce the concept of artificial withdrawal of water — and that in turn introduces the notion of "safe yield" (the rate at which water can be withdrawn from an aquifer without exceeding the rate of replenishment or recharge).

Regional differences in groundwater supplies in Alberta. (Cross-sections illustrate local geological formations.)



Aquifers vary in size: a small one may be able only to meet the water needs of a single household, while a large aquifer may supply the needs of a city.

Groundwater is said to be *confined* when the aquifer (also known as an artesian aquifer) is overlain by materials which do not transmit water rapidly. Confined groundwater is under pressure in excess of atmospheric pressure, and this pressure will determine the level to which the water will rise in a well penetrating the aquifer. A flowing well results when the water level rises above the ground surface.

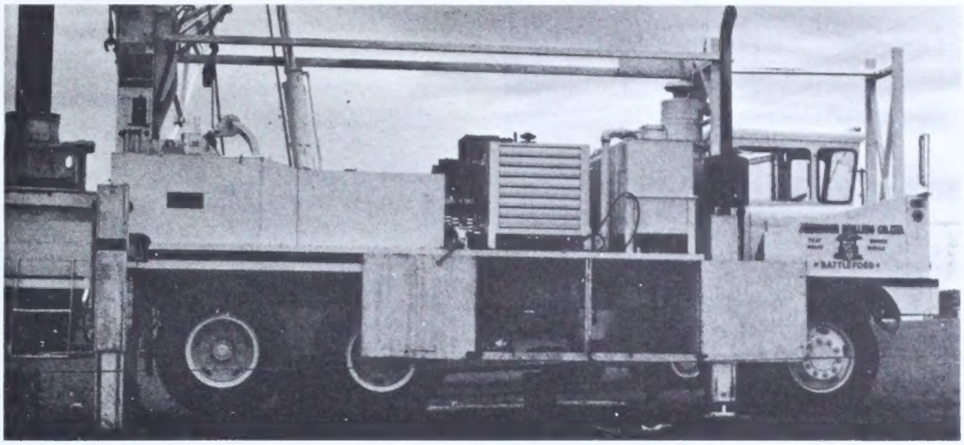
Quality is another important dimension of groundwater. Its biological and chemical properties not only determine its usefulness, but also help chart its journey through the earth. "Dissolved constituents in the water provide clues on its geological history, its influence on the soil or rock masses through which it has passed, the presence of hidden ore deposits, and its mode of origin within the hydrologic cycle," write R. Allen Freeze and John A. Cherry in their book *Groundwater* (Prentice-Hall, Englewood Cliffs, N.J., 1979).

Ions are electrically charged particles into which the atoms or molecules of certain substances (especially salts and acids) are decomposed by solution in water. A chemical analysis of rainfall or snow melt would show the water to have very small ion concentrations. But as soon as the recharge water moves downward into the soil, it begins to dissolve the various minerals it encounters, and continually increases its ion concentration. Processes other than dissolution can alter the concentration of ions. One of the most important is cation (positively charged ion) exchange. In its simplest form, this is a natural water-softening reaction. Hard waters, which contain relatively high concentrations of calcium and magnesium ions in solution, will naturally exchange these ions for sodium ions, which are commonly fixed on clay materials. Another important process common to groundwater is sulphate reduction, whereby sulphate ion concentration is reduced and bicarbonate ions and hydrogen sulphide gas (the so-called "rotten egg" gas) are added to the water.

Alkalinity and hardness are terms used in water quality reports to reflect combinations of different ion concentrations. Excessive hardness is caused by an overabundance of calcium and magnesium ions in the water. It can cause problems such as solid deposits in water pipes and the tendency for soaps not to lather. Excessive concentrations of iron can stain plumbing fixtures and laundry, and impart an undesirable taste.

The wide variety of dissolved inorganic chemical constituents in groundwater as a result of all the chemical and biochemical interactions in which it is involved gives a measure known as Total Dissolved Solids. Measured (like other chemical concentrations) in parts per million, it is an important guide to the suitability of the water for human consumption or other uses.

Some of the best — or worst — examples of abuse of the groundwater resource come from the United States, where vast aquifers are tapped to provide almost half



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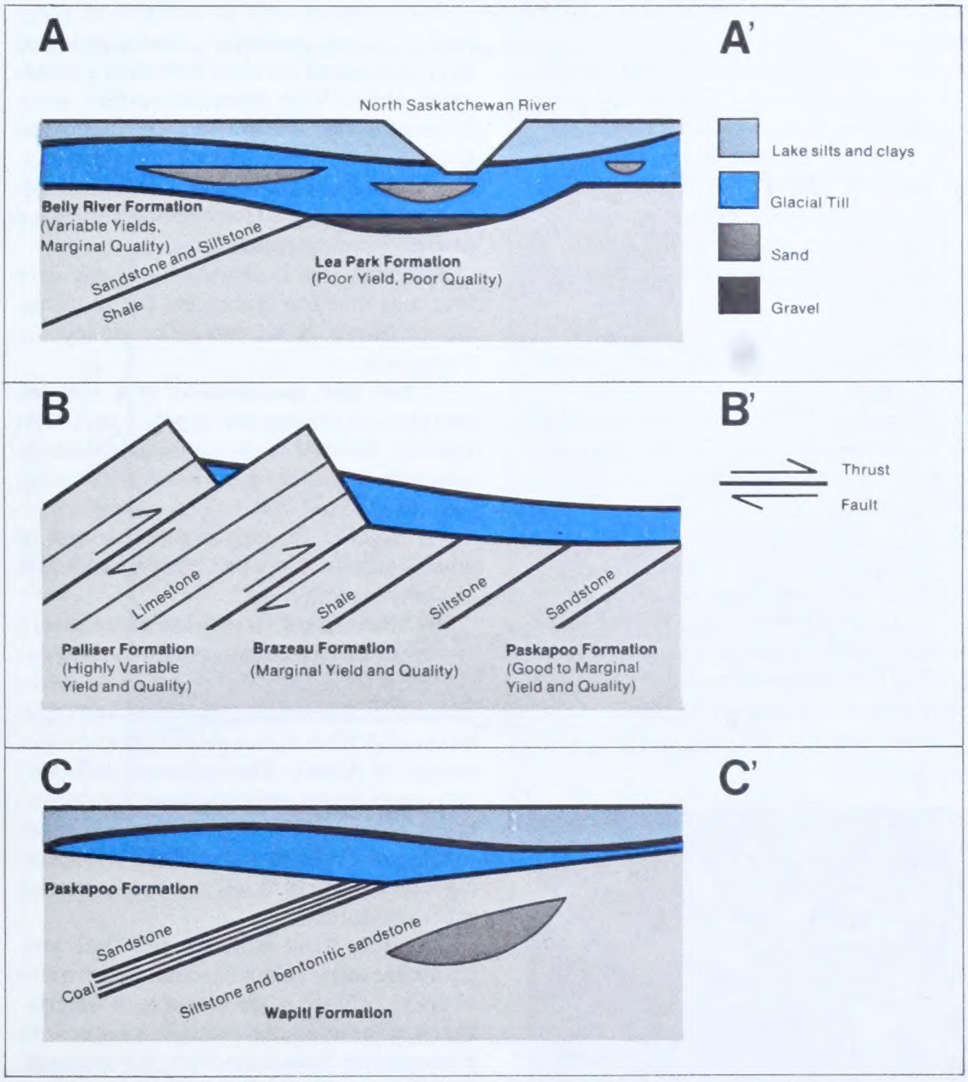
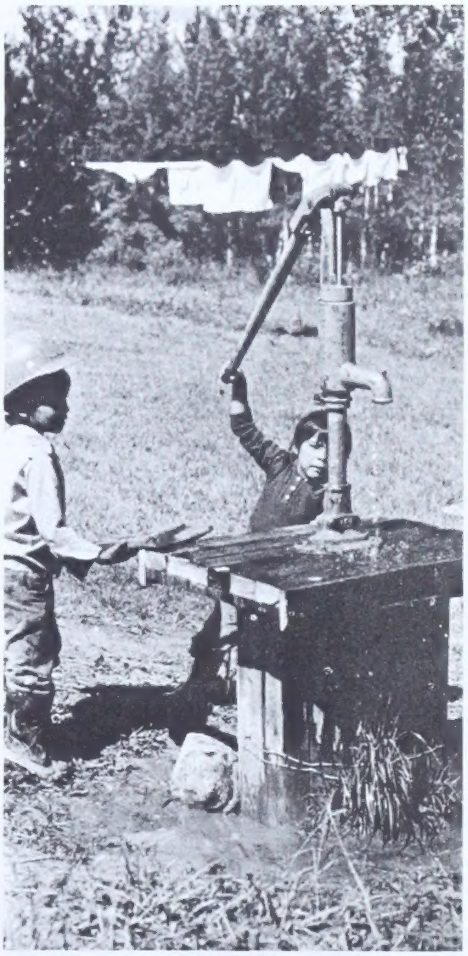


the public and industrial water supply.

Texans, for instance, have pumped so much water from the ground beneath Houston that the city has subsided more than a metre and some homes have been abandoned to invading seawater from Galveston Bay.

In the agricultural southern San Joaquin Valley in California, irrigators and other users are withdrawing annually 2.2 million acre feet more than the amount entering the groundwater supply.

Contamination is another serious concern. New York State's infamous Love Canal has demonstrated some of the worst consequences of toxic chemical pollution of groundwater supplies. But studies done by the U.S. Environmental Protection Agency note that there are nearly 200,000 landfills and unauthorized "dumps" in the country, discharging annually billions of litres of leachate into the groundwater system. Nobody knows what proportion of that volume is likely to be toxic.



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Closer to home, in 1976 an underground pipe carrying polychlorinated biphenyls (PCBs) ruptured at a factory in Regina.

Two years later, there was public concern about possible contamination of groundwater supplies (which in Regina are extensively used for domestic purposes), and the Saskatchewan government initiated a study.

The scientific panel appointed to do the job recommended extensive clean-up measures because, "although it is unlikely that the downward movement of PCBs . . . will cause a significant contribution of PCBs to wells in the Regina Aquifer System, this possibility cannot be conclusively discounted as a potential long-term threat to the quality of water in the aquifer system."

Groundwater in Alberta

The location, quality and quantity of groundwater resources in Alberta are evidence of a history that began millions of years ago. A 1978 report from the Environment Council of Alberta notes:

"Precambrian rocks are those older than 590 million years and are evidence of extensive periods of mountain building and volcanic activity. The young sedimentary rocks stacked up on the Precambrian rocks give silent testimony to the periodic invasions and retreats of ancient seas, the uplift and erosion of land and mountains, and the marked changes in climate from tropical to arctic. Surface sediments in Alberta are predominantly products of the extensive cycles of glacial erosion and deposit over the past two million years and record the advances and ultimate stagnation and melting of continental and mountain glaciers. These formations have a significant influence on groundwater in Alberta."

The Precambrian bedrock unit includes all rocks older than 590 million years. This bedrock dips to the west and forms a basement on which the younger units have been deposited.

Paleozoic rocks are hard sedimentary rocks which were generally deposited in the shallow seas that periodically covered the province between 590 and 240 million years ago. In northeastern Alberta, these rocks crop out on the surface or are covered by thin glacial deposits. But over the rest of the province they are covered by younger sedimentary rocks. The post-Paleozoic bedrock is made up of sediments less than 240 million years old and comprises the uppermost bedrock strata over more than three-quarters of Alberta. The major rock type is shale, though minor amounts of sandstone and coal are also present. Many of Alberta's water wells are in these rocks.

Overlying these rocks are surficial deposits, which typically have not yet turned into solid rock. The oldest deposits are the sands and gravels laid down along ancient rivers. While some present-day Alberta rivers flow in these channels, many of the valleys have been filled with glacial sediments and obliterated. In areas where they remain, however, very permeable aquifers are found.

The most permeable surficial deposits are recent sands and gravels found along existing river systems.

A more detailed examination of Alberta groundwater quality and quantity is perhaps best dealt with in diagram and table form (see those on Pages 4, 5 and 8). In very general terms, however, the following is the case:

- in the northeast, quality and quantity are poor;
- in the southwest (in a strip within 80 kilometres of the foothills, from Calgary north) quality and quantity are both excellent;
- in southern Alberta within 80 kilometres of the U.S. border, quantities suitable for light industry, poor in quality, are available;
- in the eastern half of the province to Cold Lake, there are low quantities and quality is marginal (with some exceptions for glacial deposits and preglacial channels).

Alberta Research Council D. Borneuf

It's probably only an accident of geography — and geology — that Canadians have been spared the worst horrors of groundwater abuse. With abundant surface water in most areas, we are less dependent on groundwater, and less likely to make excessive demands on the supply. Less industrialization, too, means fewer opportunities for serious chemical contamination.

But with less dependence we may care less, and that too endangers the resource. Groundwater is an insurance policy for Canadians.

"I feel that groundwater is a fallback resource, an emergency supply," says Don Lennox, director of the national hydrology research institute, part of Environment Canada's Inland Waters Directorate.

"It could be the only available source of good water — that's one reason we should be concerned about it."

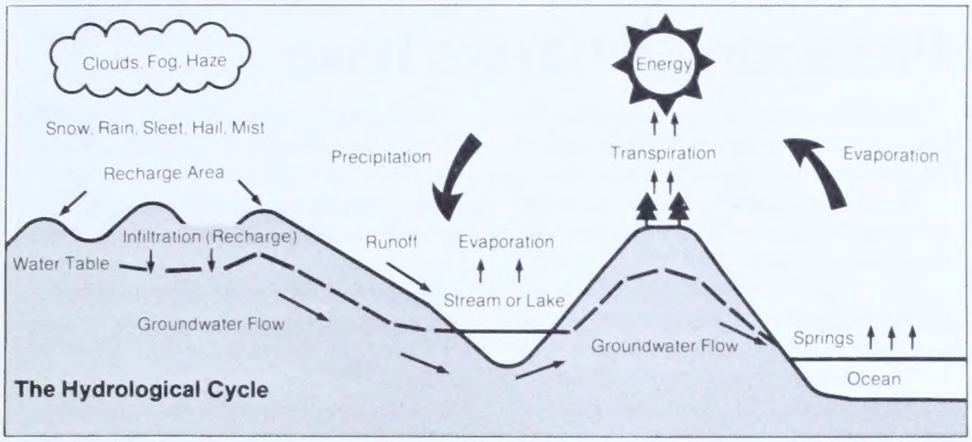
In Alberta, there is considerable concern in some quarters. Practical help to prospective users takes the form of extensive information on well-drilling, licensing and regulation of drillers (through the groundwater branch of Alberta Environment), information on treatment of groundwater for domestic use (through the engineering field services branch of Alberta Agriculture), and licensing of other than domestic users, among other measures.

Hand in hand with the practical programs are others aimed at finding out more about the nature of the resource in Alberta. Much of the work of Alberta Environment's groundwater branch involves, for example, studying the effects of development projects on the groundwater regime, and gathering baseline quality and quantity information.

The Alberta Research Council's groundwater department has just completed a massive 10-year project to produce hydrogeological maps of the province.

In view of that fact that only a small percentage of Alberta's population depends on groundwater, such efforts may at first seem surprising.

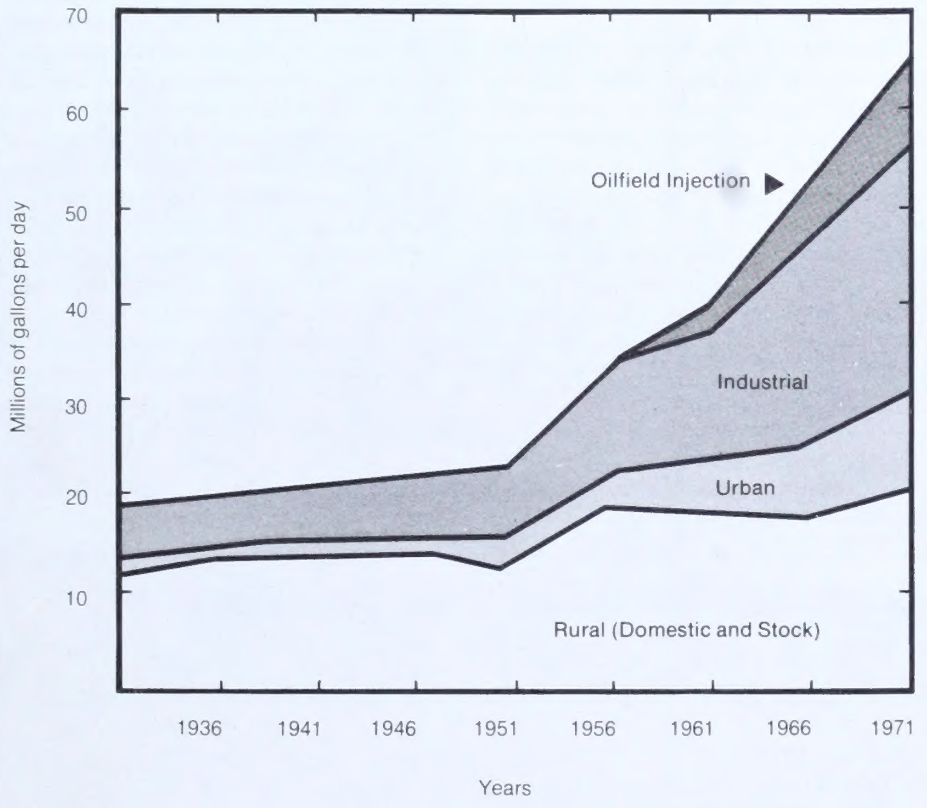
But not when you consider the fact that this percentage uses groundwater because



The Hydrological Cycle

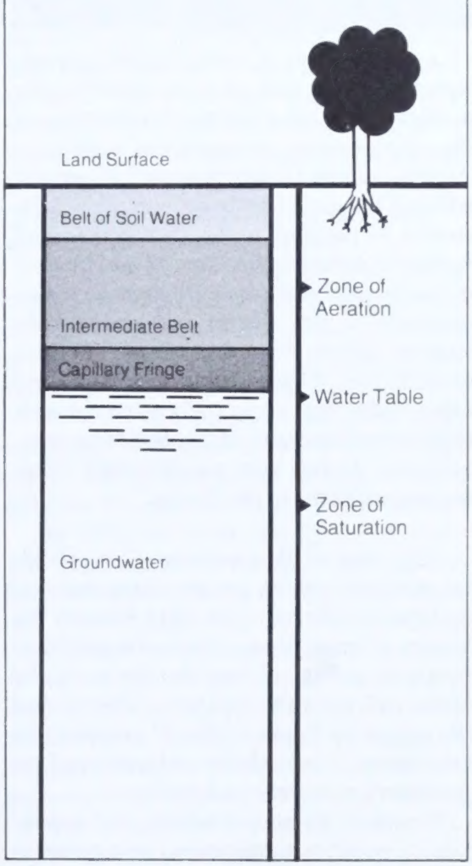
Groundwater Use By Various Sectors of The Economy, 1931 to 1971

(After Bowman, 1973)



From a 1978 ECA report on management of groundwater resources in Alberta.

Divisions of Subsurface Water



it's all there is. Especially not when you consider that groundwater is intimately linked to other parts of the hydrologic cycle — notably surface water flow and volume — which, particularly in the southern part of the province, are a general concern.

"Anything you take out of an aquifer now would be surface water some time in the future," says Allan Kerr, head of Alberta Environment's groundwater branch.

It's all a question of water balance. There is increasing recognition now of the fact that any attempts to manage water resources in general must take the groundwater component into account.

"The most intelligent approach is to study water as a whole," says Gordon Gabert, acting head of the ARC's groundwater department.

With that in mind, future research activities of the department will likely be linked to a broader water program involving consideration of surface and atmospheric water.

Even so, there are many specifically hydrogeological problems still to be solved. It's still a matter of knowing how much water is available, and at what rate it is replenished. Though such measurements can be quite precise in certain classic situations, Alberta aquifers don't always fit the pattern.

A 1978 report from the Environment Council of Alberta warns of the dangers of allowing experts to be diverted from research by the "pressing commitments to the seemingly endless problems that need solution."

That report concludes:

"The problems of management of groundwater in Alberta are still small in comparison to regions where there are broad areas

Alberta Environment files

of overdevelopment or 'mining' of groundwater resources and where competition for available supplies is intense. For this reason the groundwater management system in Alberta is able to function well at present without the need to rely on comprehensive studies of problem areas, or sophisticated computer-based techniques to evaluate regional management plans. However, in anticipation of the time when management problems in Alberta will become more difficult to deal with, Alberta Environment should begin to develop a comprehensive research program oriented towards groundwater management. Action now may alleviate some serious problems of the future."

This issue of *Environment Views* focusses primarily on the groundwater resource in Alberta. The story on Page 9 traces the history of groundwater use in the province; the story on Page 13 describes the work of a water well driller in southern Alberta; and the stories on Pages 17 and 21 consider the key factors of availability and quality of the province's groundwater supplies.

Concerns about availability and supply imply a need for management, and management can't be effective without extensive information. The stories on Pages 25, 29 and 32 discuss some of the ways researchers are able to learn about groundwater, and the specific issues that are getting research attention — and dollars — in Alberta.

The story on Page 36 offers, by way of comparison, some information about groundwater use, development and research in other parts of the world.

Gillian Sniatynski is the freelance editor of this magazine.

Protecting what we have

Because Alberta's groundwater resources are not abundant, it's important to treat what we do have with proper respect.

Three provincial Acts seek to protect the resource from the main forms of abuse: contamination and overuse.

The Clean Water Act regulates water quality by controlling the disposal of contaminants in surface or groundwater bodies.

The Ground Water Development Act ensures proper methods of developing groundwater resources. Under the Act, wells must be drilled by licensed, qualified drillers — who in Alberta only are required to have successfully completed a two-year apprenticeship program. Last year 240 drillers drilled 7,804 wells, and forwarded records of each to Alberta Environment's groundwater branch.

The Water Resources Act is designed to protect the province's water supplies, and their users, from undue demands resulting from diversion for any purpose.

Part of the Act relates to the drilling of wells for other than domestic use — domestic use being defined as use for household requirements, sanitation and fire prevention, the watering of domestic animals and poultry, and the watering of household gardens.

Users such as oil companies, industrial plants, feedlot operators, or municipalities, whose water needs are much greater than those of the individual farmer or acreage owner, must be licensed. And licences are not readily forthcoming.

Having decided on potential groundwater supply needs, a prospective user applies for an exploration permit, which carries a requirement for considerable testing and the provision of extensive field data.

If these technical requirements are satisfied, an interim licence is granted for one year, and only then can a regular licence be obtained. The licensing process was established, as a publication by three members of Alberta Environment's earth sciences division notes, "because it was felt that the development of this resource was reaching the point where problems associated with the right to direct water from some aquifers could be expected."

For some years oil companies have used groundwater for injection and pressure maintenance during their drilling and production processes. Now attention is being directed to the likely water needs of production in the oil sands. Of particular concern is the area around Cold Lake, where there are already many domestic users of ground water.

This concern has prompted even more stringent controls on the use of groundwater by oil companies in the area.

In effect the licensing process for the operators of five pilot plants in the area has stopped at the permit stage. Permanent licences won't be granted until more is known about future water supply needs and the capacity of local aquifers to meet them.

Recommended Limits for Dissolved Substances in Drinking Water

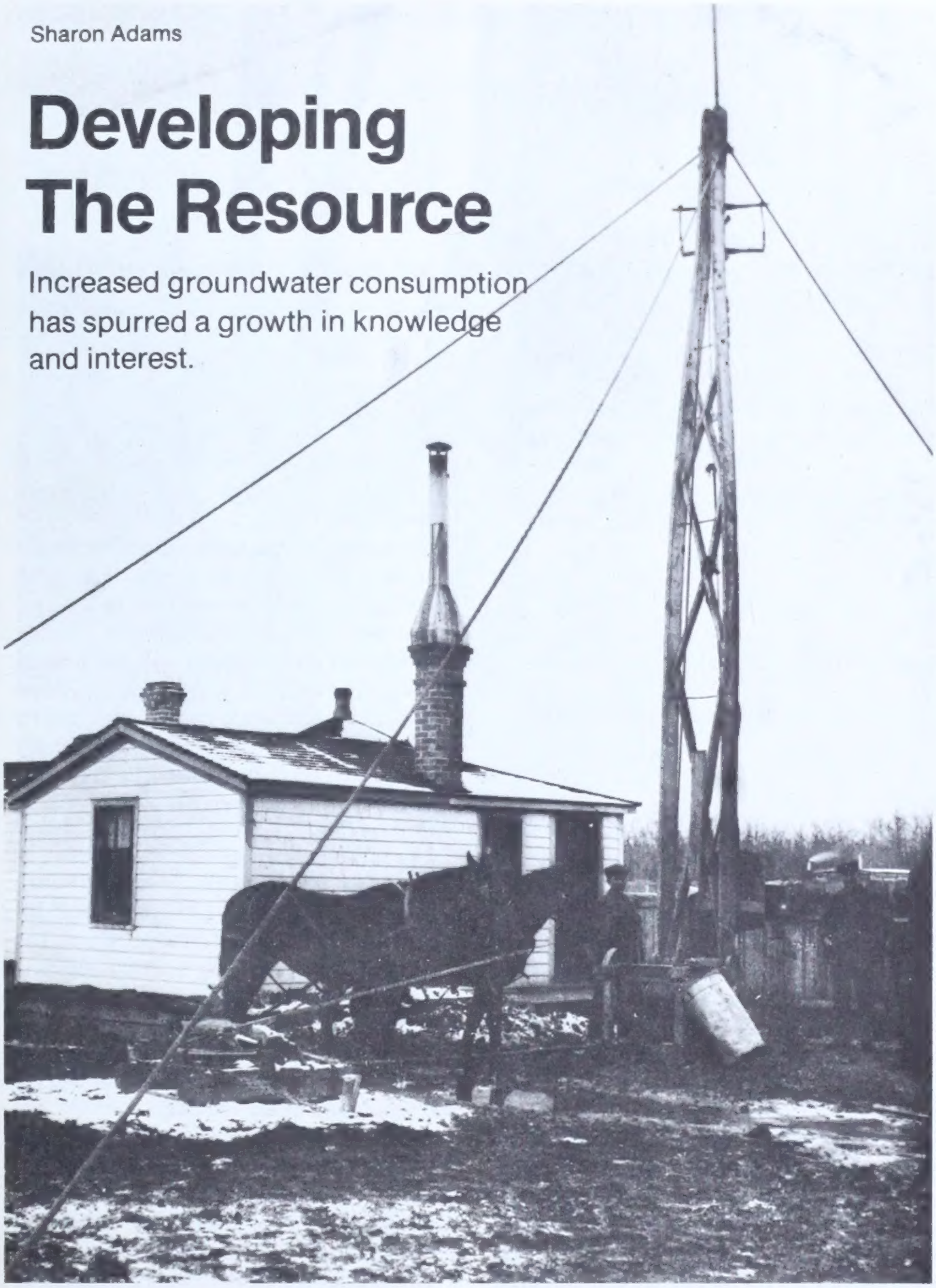
Chemical	Acceptable Limit - mg/l
Alkalinity	30-500
Ammonia as N	0.5
Calcium as Ca	200
Chloride as Cl	250
Copper as Cu	1.0
Corrosion and Incrustation	-
Iron (dissolved) as Fe	0.3
Magnesium as Mg	150
Manganese as Mn	0.05
Methylene Blue Active Substances	0.5
Phenolic Substances as Phenol	0.002
Phosphates as PO (inorganic)	0.2
Total Dissolved Solids	500
Total Hardness as CaCO	0-80 very soft
	80-120 moderately soft
	120-180 moderately hard
	180 hard
Organics as CCE + CAE	0.2
Sulfate as SO =	500
Sulfide as HS	0.05
Uranyl Iron as UO =	5.0
Zinc as Zn	5.0

Adapted from a 1978 ECA report on management of groundwater resources in Albertâ.

Sharon Adams

Developing The Resource

Increased groundwater consumption has spurred a growth in knowledge and interest.



Kepharts well-boring machine, 1903

Provincial Archives of Alberta E. Brown Collection

In the late 19th century, when the first settlers reached the dry southern part of Alberta, the province's groundwater supplies were used for machines as well as people.

Wells guaranteed the thirst of mighty steam engines, bound for the Rockies, would be quenched during the long trip across the dusty prairies.

Although wells have existed in Alberta for more than a century, most of the growth in knowledge and development of the province's groundwater resources has taken place since the Second World War, spurred by increased demand from industry and a rapidly growing population.

Originally, even the laws governing groundwater were alien. Riparian rights, allowing landowners title to water adjoining or under their land, were inherited from England's common law, and transplanted to eastern and central Canada. Their use made sense for those areas, which have humid climates and no shortage of water.

But underground water easily crosses man's arbitrary boundaries and fence lines, and in water-short areas the imported common law broke down. Battles over water access form part of the rich history of the western half of the continent.

Alberta, however, was spared the bloodshed, its development lagging behind that of the U.S. In 1894 the federal government assumed ownership of water resources in the western and northern territories, and took responsibility for granting permission for use of specific amounts of water.

When Alberta became a province in 1905, the ownership of water resources remained with the federal government. It was not until 1931, when natural resource ownership rights were passed on to Confederation's newcomers, that Alberta drew up its own legislation, which leaned heavily on the earlier federal laws.

Perhaps understandably, little research was done on groundwater resources in those early days. Most wells were dug, as needed, by hand. When the deep wells were drilled in the southern Milk River area in the early 1900s, equipment and expertise were imported from the U.S. Early data on groundwater was collected much the same way — sparingly and according to need.

Groundwater consumption is estimated to have been about 2.5 million litres per day at the turn of the century, or about 24 litres per day per capita. About half that amount would have been for domestic use.

By 1931, consumption had risen to an estimated 91 million litres or 144 per day per capita. Farms used about 55 million litres, industry 29 million and cities seven million.

By 1972, the latest year for which complete statistics were available, consumption had increased to nearly 84 million litres per day. Of that, 61 per cent or 230 million litres were used for domestic and livestock needs; 34 million, or 9.2 per cent, were used for municipal water supply; 19.3 per cent or 73 million litres, were consumed by industry; 30 million litres, or 7.9 per cent, were used in petroleum operations; and about 10 million litres, or 2.5 per cent of provincial consumption, went for other purposes, mainly irrigation.

A report prepared in 1975 for the Environment Conservation Authority, on management of groundwater resources in Alberta, pointed out that "groundwater production . . . is seldom metered," making actual determination of consumption difficult. Consumption is estimated on a per capita rate, multiplied by the number of farms, municipalities and so on with wells.

In 1921, when most farm water was drawn and carried by hand, consumption was assumed to be 72 litres per day per capita. By

Cable tool rig (above, right)

'Some's just better than others . . .'

Cortez Damberger, of Donalda, claims he's one of the best water witchers in the province.

Now 66, he has been water witching for about 55 years, since he was a lad of 10 or 11. He claims to have witched thousands of successful wells, some in other provinces as his fame spread.

"They claim about 15 per cent of people in any locality can do some part of it —some's just better than others," he says.

Damberger says he's been able to find water where even his fellow witchers have failed. Though able to use iron bars or rods of other materials to find underground water, he prefers a Y-shaped willow crotch.

Holding the wood level with the ground, he walks slowly back and forth over an area until he feels a strong downward pull — but it's not always water that makes the stick quiver.

"There's many other things that'll pull you — minerals and gas, for instance," he says. That's where his unique talent comes in, and why farmers and ranchers are willing to pay his $50 fee.

"What happens is you have to cipher it out by the way your stick moves," he says.

Damberger claims he can not only tell where there's a "water vein." By counting each bob of the switch as one yard, he can also tell the depth needed to drill, and can estimate the eventual flow.

He's not quite sure how he gained the talent. Maybe it's inherited, he muses, since a German uncle and one of his own daughters have been able to witch wells.

"Some say it's because I was born under a water sign (a Jan. 21 birthday makes him an Aquarius).

But Damberger thinks perhaps the best explanation is that he's more sensitive than most to electric current or magnetic fields.

"I think you act something like an armature on a generator or a magnetic field," he explains.

Damberger says he's had a few dry wells in his career, though he adds "sometimes drillers, when they use a rotary rig, plug your vein off."

But the scientific view of water-witching is more skeptical. Though farmers and ranchers by the hundreds seek out witchers each year, most hydrogeologists and drillers think witching is so much nonsense.

Roger Clissold, senior hydrogeologist with Hydrogeological Consultants Ltd., the group which in 1975 helped prepare a major report on groundwater resources for the Environment Conservation Authority, is more forgiving than most, but still skeptical.

His attitude is that witching can't hurt and "four times in my experience witchers have chosen locations with higher yields than what I found."

On the other hand it may be just luck. Clissold says it's not uncommon for drillers to find a good water flow from a well in one spot, but be unable to get a flow in holes drilled only a metre or so away.

"And once, using aerial photography, I was able to find water a witcher overlooked."

He adds that, through most of the province, the chances of getting a dry hole are small in any case — though when a well is drilled, the flow may not be as high as desired.

"If I choose a site based on hydrogeological evidence, I narrow it down to anywhere within, say, four hectares. If somebody is willing to come along and say, drill in one spot in preference to another in the area," he'll do it.

But Clissold admits that when a witcher is right "I can't explain what's happening."

"Some crackpots do it for show, but I wonder if some of them don't feel something — they seem to go through a lot of anguish to hold on to their rods or twigs."

He debunks one theory that witchers are simply acting on observation of subtle surface evidence which could point to the location of the best groundwater well site.

"My master's (degree) work was on that — linking natural features and groundwater incidence." Yet, he says, his trained eye cannot always pick out the one spot where the flow will be best.

So his advice to clients who inquire about witching is that it can't hurt.

"On a $25,000 or $50,000 project, witching will cost $25 — and they won't even feel that."

It all comes down to faith, he says, like "whether you believe in ESP (extra sensory perception) or not."

While the scientific mind may reject such para-normal occurrences, obviously the water-seeking public in Alberta is not about to abandon all faith, and Damberger could have a witching career for many more years.

1971 it had risen to 336 litres per day, reflecting the use of modern appliances and in-house supply.

As domestic consumption has increased over the years, so too has groundwater use by industry. Alberta Environment estimated in the early '70s, 26 million litres per day were used by such industries as coal mining operations, sand and gravel quarries, food processing operations, rubber and plastic manufacturing, the paper products industry and in mineral, chemical and utilities production.

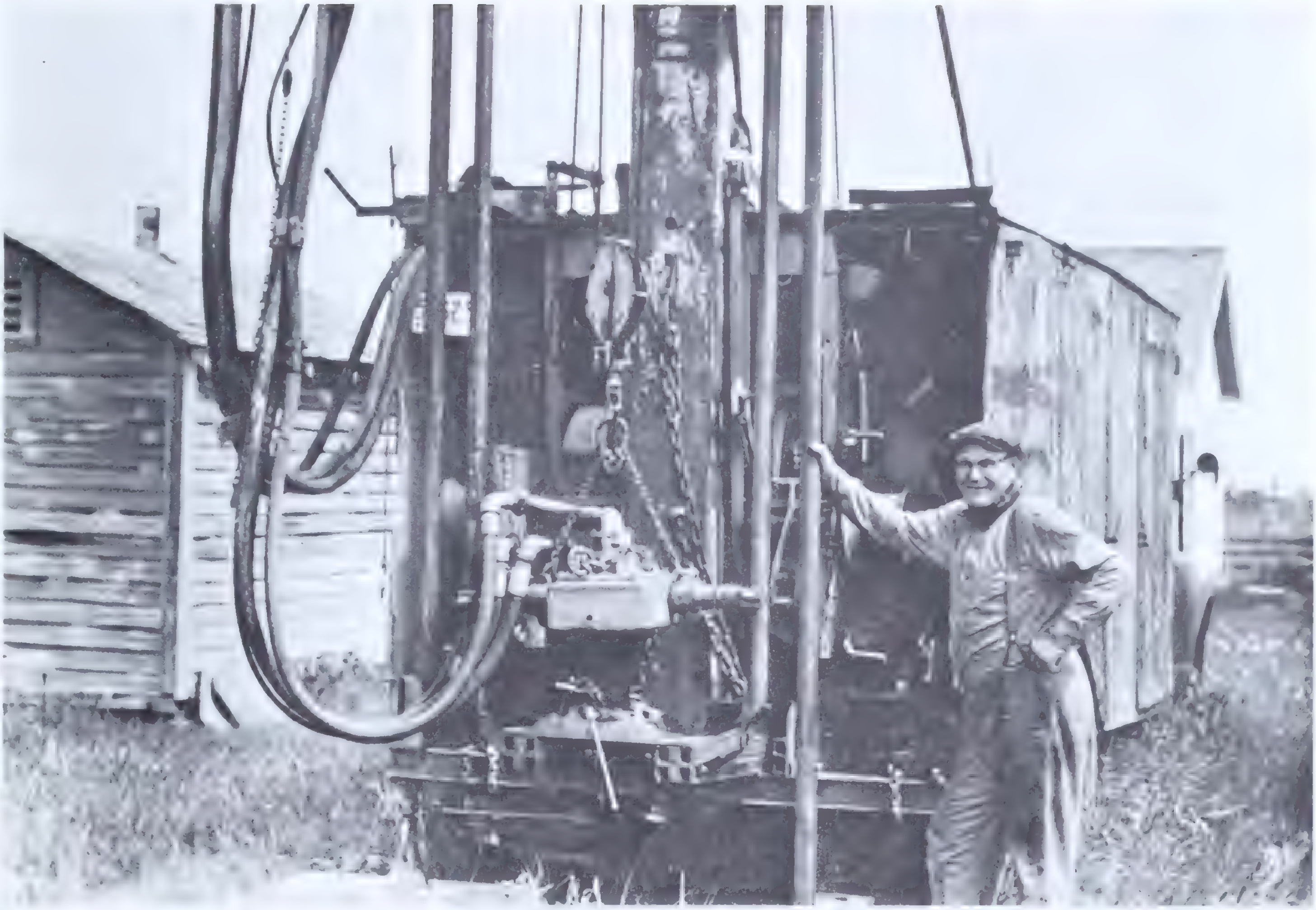
The oil industry became a significant user of groundwater in the mid-'50s, when groundwater was used in secondary recovery programs. By 1971, its consumption had increased to 29 million litres per day. It is estimated that as drilling activity declines, so will the oil industry's consumption of groundwater.

Naturally, as the uses for groundwater increased, so did the need for knowledge and regulation of the resource.

Concentrated effort since 1955, when the Alberta Research Council (ARC) began groundwater studies, has resulted in a considerable body of knowledge, a considerable reputation for groundwater research and a spin-off benefit of attracting a number of hydrogeologists and other groundwater scientists to the province.

The first objective of the ARC's groundwater department, says its acting head, Gordon Gabert, was a systematic evaluation of the province's groundwater resources. Through regional studies throughout the province, the groundwater department has been able to tabulate distribution, availability, natural movement, replenishment and depletion of groundwater, anticipated well yields in a given area and chemical quality of samples from various sites.

This task was made easier by access to well records filed under provisions of the 1953 Groundwater Control Act, which required drillers to submit logs and other data from their wells. In addition, the department has established a number of observation wells, varying up to 100, from which it can



Alberta Environment Photos

gain experimental and observational data.

Al Kerr, head of Alberta Environment's groundwater branch, says the ARC "fathered groundwater development in Alberta," and has supplied professionals to other groundwater departments internationally.

From the original small operation in the mid-'50s, he says, the ARC has contributed to a growth in expertise resulting in Alberta now having "the largest community of groundwater people in North America," including 30 to 40 groundwater consultants and as many government-employed specialists.

In addition to collating data from well logs and its own observation wells, the ARC has undertaken a number of special studies in geophysics, natural groundwater movement, groundwater chemistry, aquifer and well engineering and watershed research.

All of this has resulted in an extensive data bank which can provide a valuable basis for further research. (It can also help a landowner or drilling contractor anywhere in the province find water where it's needed.)

Alberta Environment took over responsibility for disseminating this information from the ARC in the early '70s, to allow the researchers to expend their resources on research.

Kerr says Alberta Environment's groundwater information service fielded two thousand public inquiries last year; in some cases it gives out quite specific information drawn from computerized records of ARC data. For example, details can be given of the depth and quality of wells within a given distance of a chosen site.

In areas such as the northeastern part of the province where hard data is limited, Kerr says Alberta Environment is able to make interpretations from the basic geology of the area, which may prove valuable in locating water.

Though the large urban areas are mostly supplied by surface water, Kerr says it's important to remember that groundwater "is still the mainstay of farmers and ranchers."

In general, he says, except for the north-

Alberta Environment photo

Alberta Environment photo

east, Alberta has enough groundwater for domestic use for those who must depend on it. The sites of industrial development, however, may be determined by the availability of sufficient groundwater — though "with abundant surface water, most locate where there's enough of that to meet their needs."

The accumulation of scientific data and expertise was bound to rub off on the drilling contractors, who actually bring in the wells.

Between the '30s and '50s most wells in Alberta were developed by part-time drillers and there were some fly-by-night operators whose wells later collapsed or ran dry. In 1958 the Alberta Water Well Drillers' Association was formed, and technical sessions and seminars presented at its annual convention were the major means of passing on information about new equipment and methods. Then in 1977, drilling contracting became a registered trade.

Before licences could be granted, all drillers with less than 10 years' experience had to pass provincial examinations. Following the tests, 245 contractors received licences. Today there are about 270 licensed contractors.

Apprentice drillers require 3,600 hours of field experience, and class studies which can be completed in two five-week courses offered at Red Deer College. In 1980, 12 apprentices were qualified and about two dozen are enrolled in the program this year.

In addition, the new regulations under which drilling contractors are licensed also contain standards for equipment and performance designed to maximize well life and water purity.

Despite Alberta's excellent research reputation, continued growth will present new challenges.

Before long-term "safe" well yields can be established, the natural recharge rate of groundwater must be determined.

Aquifers in Alberta are poor in comparison with those of eastern Canada and the U.S., but the slow-flowing, low-pressure aquifers, combined with later industrial development, has kept groundwater resources here relatively unpolluted. Increased industrialization may pose some problems, however.

While municipal and farm demands are projected to decrease as people move away from the farms and municipalities opt for water supplied by pipeline, rapid growth in acreage development is expected to keep domestic demand increasing.

Industrial use of groundwater is projected to increase as well, posing problems of availability and perhaps overuse.

Deep-well disposal of wastes, developing oil sands and coal degasification projects and many other, as yet unforeseen, factors will combine to ensure the search for knowledge in groundwater development will continue.

Sharon Adams is a journalist in Calgary

Jack Spearman

The Driller At Work

Three generations have developed the 'territory' — and much of the knowhow.

Jack Spearman

As his rig throbbed away in the background, Roger Parsons looked across the rolling farmland north of Cochrane.

"I figure this one may have to go down 48 metres or so." He cast a glance at a farm a couple of kilometres over. "I drilled a well over there near those buildings and had to go down 60 metres."

In Parsons' head is a chart of the shallow geological formations of the area and where the aquifers run. It likely rivals the maps compiled by the extensive resources of government and industry.

Like most water well drillers in Alberta, Parsons has his own territory, and the area around Cochrane and Calgary is his. It also belonged to his father and his grandfather who in 1934 made the first lines on that mental map. The lessons have been passed from father to son to son: Parsons himself learned how to drill a well from the time he was knee-high.

"I've got a drawer-full of drilling logs at home," he said. But you get the idea they are kept to satisfy the province's appetite for paperwork and are seldom consulted once a job is complete.

"Yeah, most of it is up here," he added with a tap to the forehead. "If I came in from out of province, it would be much more difficult."

Parsons Drilling in many ways is typical of the industry in Alberta, small and owner-operated. There are about 265 licensed drillers in the province, 80 per cent of whom own two rigs or less, like Parsons. And while equipment and trucks on which the rigs are mounted are improving, most drillers have a territory about 80 kilometres across and seldom stray outside.

Like most drillers, Parsons does about 90 per cent of his work on farms and ranches, most often for stock water. He does a few jobs a year for acreage owners wanting household wells, and the rest are industrial and municipal. For example, he has drilled wells for the village of Cremona.

Parsons, who has been on the executive of both the Alberta and Canadian water well associations, says merely drilling a hole in the ground does not guarantee a useable water supply.

Finding water in this province, even in the semi-arid southern regions, is seldom difficult — Parsons estimates about 95 per cent of the wells he drills come in wet. But there are other problems.

In some areas, especially near Drumheller and Brooks, drillers have to be careful to avoid striking pockets of natural gas. In the Bragg Creek area west of Calgary, the underlying strata of black shale sometimes refuse to yield a drop.

And even striking water is no guarantee either of adequate quality or flow.

Wells near Chestermere Lake west of Calgary often come in contaminated and Parsons estimates four wells might have to be drilled to find one good one. (The contamination, he suspects, comes from ground contaminants which have found their way into the water table via old wells with decaying casing.) In other areas, the sulphur content of the water makes it foul-smelling.

Parsons said owners of small acreages sometimes don't find enough water. They have to construct reservoirs to store the inadequate flows from their wells and supplement that by having water trucked in. Two Calgary firms do nothing but haul water to such sites.

In drilling a well, there may be nothing on the surface that tells where water lies below. Advances in hydrogeology notwithstanding, many landowners still call in witchers before they call in drillers, Parsons said.

Jack Spearman

If no witcher has been called in, Parsons surveys the site and plans the well in relation to distances from buildings, sewage lines and utilities. (Provincial regulations specify minimum distances.)

Calling on his mental map, he usually has a good idea how far down water is, but admits that at this stage of drilling there's an element of guesswork.

Parsons' equipment differs from most rigs in southern Alberta. He has cable-tool rigs which use a one-ton weight literally to hammer casings into the ground, pounding away at a full throttle rate of 58 times a minute.

A tool, called a dry block, is clamped on to the drill stem and the first piece of casing is attached. The hammering begins, and slowly — often just a few millimetres per stroke — the casing is forced into the ground.

As it sinks, additional pieces of casing are screwed on and the process continues.

Wide casings — up to 40 centimetres in diameter on Parsons' equipment but usually 11 to 14 centimetres for farm wells — are used until bedrock is struck. At that point, smaller casings are inserted and the operation continues down to the water table.

When water is struck, usually about 42 metres down in the Calgary area, the narrower casings are pulled out and a perforated pipe to allow the water into the well replaces it. Then, pumps are installed and the water brought to the surface.

It takes about three days to drill an average well in the Calgary-Cochrane area — a week or more if drilling strikes a tough gravel bed which the forces of geology can turn as hard as concrete.

"Those are the most frustrating wells," said Parsons. "Sometimes we have to use dynamite down the hole to get through."

The most common type of drilling rig in southern Alberta uses the rotary method, much the same as an oil and gas rig.

Jack Spearman

A drill bit chews through the ground while the casing to which it is attached is rotated. Meanwhile, water is fed down the hole and pumped back up to get rid of debris.

Rotary rigs are used where geological formations are easier to penetrate, and when new casings are added during the drill, they are usually six metres or so long.

Parsons' cable-tool rig may use casings as short as two metres — and stouter to withstand the greater pressures of hard formations.

In northern Alberta and in the south around the Cypress Hills in the southeast, a boring rig is used. Like a giant auger, it digs at holes up to a metre or so across, wide enough to allow a bucket down to haul out dirt. This method is used in areas where the water table is relatively high — perhaps only 12 metres down — and where underlying formations are quite soft.

Drillers hope farm wells will come in at about 50 litres of flow per minute while 25 litres is adequate for household wells on acreages.

Parsons said the industry is more tightly controlled now than in the past, but unlike many small businesses who complain about mounds of red tape, he does not think drillers are over-regulated.

One of the major steps forward, he said, was the decision in 1977 to require all drillers to write a test to get a licence, and the establishment of apprenticeship programs. While Parsons demonstrates the benefits of learning at his father's knee, he now also sits on the advisory council to the province's drilling apprenticeship program run out of Red Deer College.

The industry was in bad shape 10 years ago when seismic drillers swung into water well drilling in their off-seasons to keep their rigs occupied. The result, said Parsons, was substandard work by firms whose expertise lay in other drilling operations. The licensing stipulations have stopped that, and proper standards have returned, he added.

For the 70-odd wells he drills in a year, Parsons must fill out drilling logs — basically a diary in triplicate of how the well was sunk and at what depth it came in.

The property owner gets one copy, the driller another, and the third must be filed with Alberta Environment within 60 days.

Special permits must be obtained if a driller goes deeper than 150 metres. Parsons said wells seldom go that deep; the limit was set to ensure water drillers avoided oil and natural gas.

Though no permit is needed to drill a well for domestic use, the paperwork gets much more demanding when municipal or industrial wells are drilled; the province keeps a tally on demands made by heavy users of the groundwater resource.

While many sons rebel at the thought of following in their father's footsteps, this has not been the case with the Parsons family. With two young boys at home, Parsons is hopeful a fourth generation of water well driller is in the offing.

"There's a very satisfying feeling you get by drilling a well for a farmer or rancher," said Parsons. "You know you're doing some good."

Jack Spearman is a journalist in Calgary

VIEWPOINT

Maurice Lewis

'Alberta Environment administers the water well drilling industry and it is this factor which in many instances raises the hackles of a water well driller . . .'

Groundwater — the very word presents an aura of mystery and misunderstanding, yet it is our most valuable renewable resource. Man can live without food for a considerably longer period of time than he can without water, and the old adage that "you never miss the water till the well goes dry" is certainly a profound truth.

During the last decade the water well drilling industry has witnessed change of more magnitude than in any previous time. Government regulations, educational seminars and training programs, and a general awareness by water well drilling contractors have contributed in general to an upgrading in management of our groundwater supplies.

However, many of these changes caused confrontation between government and the private sector, and in some aspects this situation continues to exist. Alberta Environment administers the water well drilling industry and it is this factor in many instances which raises the hackles of a water well driller when change is forced upon him.

The largest percentage of water well drilling firms in Alberta are owner-operated. The water well driller, by the very nature of his occupation, tends to be an independent, individualistic person. Because of the nature of the trade a customer has to rely not only upon the driller's practical knowledge and ability, but also upon the company's integrity and ethical modes of conducting business. More often than not, he (the driller) lives in a rural area, conducts a large percentage of his business with another independent individual, namely the farmer, and is generally accorded a certain amount of respect because of the unique knowledge that he has acquired. One can therefore expect confrontation when drastic change or interference is forthcoming.

In the late 1960s the industry was forewarned that regulations would be necessary unless the quality of water well drilling was upgraded. This led to the publishing of a set of well construction standards by the Alberta Water Well Drilling Association. In 1973 and 1974 the designation of water well drilling as a trade under Alberta Labor regulations was realized. This led to the certification of drillers and eventually to a full-fledged apprenticeship training program. However, the training program would not have become a reality if Alberta Environment had not revised the Groundwater Control Act to regulate the issuing of annual drilling licences only to firms with journeyman drillers on staff.

That particular regulation did not seem to cause consternation within the industry in general, but it did serve to arrest the apathy that seemed to exist concerning a training program. The one policy that did arouse the industry, and is still a latent, lingering source of hostility, was the use of government drill rigs and professional personnel to conduct test wells for individuals and communities. This was and is an interference of government in a private enterprise society. The industry had asked for legislation to tighten up instances of poor well construction and workmanship, but we had not asked for government to be drillers and consultants. When the private drilling sector became increasingly aware of this situation, the A.W.W.D.A. protested as the voice of the industry. As a result, the use of government equipment and personnel has assumed a lower profile in recent years.

However, the total abandonment of Environment's involvement in this sector is not completely evident yet and another facet of interference could present itself in the near future. This matter concerns the industry's training program. Having co-ordinated the program for the last two years, I have found every government agency concerned most helpful and co-operative. At the present time, however, I discern an involvement by Environment in an area which really does not concern it.

The bulk of the credit for establishing and implementing the apprenticeship program belongs to the Alberta Water Well Drilling Association and Alberta Advanced Education and Manpower. True, Alberta Environment gave an impetus to it by revising the Groundwater Control Act, but the fact remains that this program has to be the responsibility of the industry and the Apprenticeship Branch. Other provincial drilling associations are now seriously considering similar programs. It should be the A.W.W.D.A. and the Apprenticeship Branch who explain, assist and otherwise aid or respond to these requests for assistance.

If the request for information regarding these educational training programs comes to Environment innocently misdirected, Environment should refer the request to the proper source.

I feel that the time has now come when we must assume a practical, common-sense approach to policing of existing regulations, urge our own industry to support our training program to the utmost, and leave the regulations as they exist, in their present revised form. Let private enterprise be exactly that, "private enterprise." I feel that the onus to provide competent, ethical services to the consumer now lies with the water well drillers. Environment must police, to the full, where individual delinquent drillers are concerned, but our own organization must also take responsibility for promoting the upgrading of practical and ethical standards within the trade.

Maurice Lewis is a water well drilling contractor and until April, 1980 was secretary-manager of the Alberta Water Well Drilling Association. He also co-ordinates the water well training program at Red Deer College

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Alberta's Groundwater Supplies

They'll need careful management in some areas.

Pumping test to evaluate an aquifer for use as water supply for the town of Olds (abc

One of the biggest problems in coming to grips with possible shortages in groundwater supplies is the "out of sight, out of mind" attitude that tends to lead many people to believe that the flow will be endlessly forthcoming.

"It seems to be generally taken for granted that groundwater is just something that's always going to be around," says Bill Shaw, a senior planner in the regional planning and research section of the Red Deer Regional Planning Commission. "When we did our regional plan open house canvassing, there were very few questions on groundwater raised by the public. Only two people seemed worried about groundwater shortages in the future, and their concerns were on potential effects of seismic drilling operations."

Mary Gordon, a research officer with the environment council of Alberta, also found in a recent survey that Albertans mostly seem to feel that their groundwater supplies are adequate and well managed. But the picture may not be quite as rosy as that, and future growth and development in the province may make it less so.

To begin with, Alberta doesn't have an excessive supply of groundwater.

"In most areas of the province, we have enough for our domestic needs," says Allan Kerr, head of Alberta Environment's groundwater branch. "But we don't have vast resources such as you'd find, for example, in California and Texas, where you can get wells flowing at a rate of, say, two thousand gallons a minute."

An aquifer, he explains, can hold a certain amount of water, and it's theoretically possible to calculate how much can be taken out each year without depleting the resource.

"When you're tapping a groundwater supply, some of the water will be replaced each year by precipitation. If a community or some other project draws off more than the amount that's replaced annually, the aquifer will begin to dry out. In this kind of a situation, you should be planning far enough ahead so that as your community grows and increases its demands for water, you're ready when the time comes to put in a pipe-line or to turn to some other form of water supply before the aquifer is over-used."

Farmers, acreage dwellers, and residents of many smaller Alberta communities are dependent on groundwater supplies, and Allan Kerr warns against the practice of "water mining."

"Down in California and Texas, they have a major agricultural industry that's

Allan Kerr

based on 'mined' water — that is, groundwater that's being used up faster than it's being replaced. And they don't have a long-term alternative ready to turn to when the 'mines' run out — there isn't much in the way of other water sources to support the size of the operations they now have."

So far, in Alberta, there is no indication that water supply problems of this magnitude are likely to develop. But the groundwater supplies we do have need to be carefully managed and conserved in some areas of the province in particular.

In the southern part, where the dry climate makes the recharging of aquifers a slow process, population growth is limited by the scarcity of good water; most of the population increases take place in the larger communities near surface water supplies.

In central Alberta, groundwater is fairly plentiful, and many smaller municipalities rely on it.

The Peace River area in the north is less well endowed, and useable groundwater is especially hard to find north and east of the Peace River.

Overall, groundwater in the south tends to be used mostly by smaller towns and farms, in the middle of the province by acreages, municipalities and farms, and in the north increasingly by oil and gas operations.

More than half the municipalities covered in the ECA survey indicated that their future demands on groundwater would increase, and it seems likely that, in the northern and central regions in particular, industrial growth, urban expansion, and an increase in the number of acreages will make for heavier groundwater withdrawals.

At the same time, there are already practices which are causing, or could cause, unnecessary and significant groundwater wastage.

Bill Shaw suggests that some agricultural drainage schemes, while making more land available for production at the moment, may have some impact on water availability in the future.

"When you see sloughs and muskegs being drained, you can't help but wonder what this is doing to the groundwater systems. I've even heard farmers themselves complaining that the water supplies aren't what they were forty or fifty years ago. It seems to me that we're running into a 'catch-22' situation here, with a real conflict between agricultural and environmental issues. On the one hand, we want to increase the amount of land under production, but on the other we don't want to do some long-term damage to the environment. It's probably too early to see what the long-range effects of drainage will be but I think we should be more concerned with looking into this."

In the Red Deer commission area, most of the towns depend on groundwater.

"And some places, such as Stettler, are

Increased acreage development will also increase demands for groundwater (below)

AAH...!
24 LITRES DOWN,
24 TO GO!

already having to dig deeper wells or to look further afield. Right now, though, groundwater problems aren't a high priority with us."

Robert Botham, director of the Battle River Regional Planning Commission, agrees that agricultural drainage may be an unwise depletion of groundwater, but believes that projects such as the slough drainage in the Flagstaff area were "probably a wise decision."

"It put quite a bit of ground into grain which will be of benefit to this generation and the next. But I would like to see a lot more research done before we go into anything like the Flagstaff scheme again."

Actual farm operation takes water, and Robert Botham points out that some forms of farming can use a great deal of groundwater.

"Generally speaking, livestock is a great deal more demanding than grain farming. A cow, for example, will use about 48 litres a day. Grain growing can get along with much less."

In the Battle River planning commission's area one of Alberta's biggest cattle and hog producing regions runs in a belt between Pigeon and Gull lakes. Mary Gordon notes that production there is expected to increase four-fold by the turn of the century, and emphasizes that the key to this growth is "secure groundwater supplies."

Such foresight means planning of two types — the avoidance of wasteful practices such as large-scale drainage, and the management of development so that too much groundwater isn't used over a given period of time.

"Filling up an aquifer," as Robert Botham puts it, "is a bit like letting water slowly leak out of the bottom of a bathtub — the water gradually soaks down through the soil till it reaches the water table and becomes part of the groundwater. About seven per cent of our annual precipitation goes down through the ground in this way. Now, if you reckon that the yearly precipitation is about 25 to 45 centimetres, you can figure out how much water is being put into an aquifer over a

A philosophical dilemma . . .

Run out of groundwater? It's not really possible. While local shortages may occur, the global supply of subterranean water is self-perpetuating and to some extent self-regulating.

"Normally, I would say, the amount of water withdrawn will be governed by the availability," says Dr. Jozsef Toth, groundwater specialist with the University of Alberta. "When people start to notice that no more water can be developed, then no more development will come in there. This natural and historical evolution has been deliberately violated in some parts of the United States."

Arizona, Nevada and parts of California are known for their major groundwater supplies in intermontane valleys. They have little recharge, however, because of the region's aridity. Bearing this in mind, the American states have deliberately encouraged industry into the area which will use more of the water supply than can be replaced in the same period. Eventually the water reserve would be depleted. Before this time, the Americans plan, water will be piped in to replace the exhausted groundwater — paid for with profits from the arid-land industries.

Toth says this kind of deliberate overuse for strictly economic reasons is very rare, and possibly unique to the United States. A more basic consideration governs the decision in north-east Africa — survival.

"The Nubian Sands — a huge artesian aquifer covering 10 million square kilometres, largely underlying the Sahara — receives very little recharge but has large amounts of water stored in it. This water is being developed for agricultural developments, for irrigation purposes in parts of Egypt and the Sudan.

"However, there are fears that when this water runs out at the proposed rate of development, then all the green land that will be established on the strength of this water will also have to disappear. The recharge, the replenishment, is much lower than the proposed rate of development."

New vegetation could slightly increase the infiltration rate of the now-desert area which supported lush forest thousands of years ago, until the region's climate changed. Loss of forest cover accelerated the desertification of the Sahel and other parts of Africa, environmentalists now believe. The difference would be insufficient to balance the water account, however, with its scant one to two centimetres annual rainfall. Water from the Nubian Aquifer could last several decades — no more than that. Then, farmers or workers in the newly-developed area could be forced to leave.

"Should these experiments fail or not turn out, there will always be time for those people to move out and just leave the land as it was."

Would food supply and even lives then be endangered by loss of briefly-productive land? Do we have the right to alter the earth's surface?

"This is a philosophical question, and I am not a moralist in this regard," says Toth. "I believe humanity does whatever it considers expedient at the moment, and there's no way one can evaluate whether it's right or wrong and whether we have the right or do not have the right.

"If we have the ability apparently we can do it. As long as we don't hurt anyone else knowingly, I have no objections. Well, we can hurt ourselves, perhaps, but I don't think that good Mother Earth will object to it."

Flow from the dewatering operation at Forest Green (right)
Flowing well, Grande Prairie (below)

Tim Beier

particular area."

This information helps in calculation of a "safe yield" usage figure, which sets a limit on how much water can safely be drawn from any aquifer.

"We worked it out that, if the average family uses 960 litres of water a day, we would have to limit the number of lots per quarter-section (64 hectares) to twenty-four."

The three regional planning commissions covering the southern part of the province have set a proven water supply as a precondition of subdivision approval. The Palliser Regional Planning Commission limits rural subdivision to not more than three adjacent parcels of land in an attempt to avoid the possible impact of such developments on neighboring agricultural operations as well as on the groundwater supplies of a larger area.

Such detailed planning is, however, relatively recent, and some older developments without the benefit of "safe yield" guidelines now are facing water shortages. Some acreages west of Calgary, for example, must have water trucked in as their wells have gone dry.

But the problem of distributing people to prevent overuse of groundwater may be, to some extent, a self-solving one as communities find themselves unable to expand because of the limitations of water supply. Already, towns such as Wembley, Sexsmith, and Clairmont are facing a serious constraint to their growth unless other sources of water can be tapped.

A more obvious type of overuse, and one which is patently less justifiable, is the practice of allowing artesian wells to flow freely and putting little of the water to use.

"You'll find these so-called flowing wells pretty well all through the province," says Kerr, "but there are a large number particularly in the Milk River basin and in a band 160 kilometres east of the foothills. Basically, the problem is poor construction of the well to begin with. If you build the well so that flow can be controlled, you can cut down enormously on the wastage. For instance, if you set the flow at a gallon (4.8 litres) a minute, that's enough to keep the water from freezing and is a lot less of a flow than these wells have now."

But it's not easy to stop or decrease the flow from existing wells.

"You can't just go ahead and seal off a well. If you did that in the Milk River area, all you'd be doing is increasing the pressure in some other well so you wouldn't be saving any water. Besides, some of these wells are in rivers and reservoirs and would be very difficult to get at to seal off."

Most flowing wells are drilled intentionally to provide water for agricultural or domestic use but some other borings have caused water waste more as an unforeseen by-product.

In parts of the foothills there are seepage areas resulting from seismic exploration drilling. In some cases, water losses are comparabale to those of a flowing well.

While some subdivisions are limited by a shortage of groundwater, others (like the Forest Green development at Stony Plain) may have too much. Water removal by continuous pumping, or "dewatering," may be needed.

Blaine Usenik, general manager of northern development for the Daon Development Corporation, explains that the water table under Forest Green had to be lowered about three metres to allow deep sewer lines to be installed.

"If we hadn't drained off the water, we wouldn't have been able to bed the line properly — it was very wet silt down there."

Usenik says the drainage problem wasn't anticipated when the development was planned — and he believes such snags are rare.

Though some of the Forest Green groundwater surplus is being put to use (Usenik believes it waters the golf course), dewatering usually means wasting a water supply which happens to be inconveniently located.

Robert Botham believes that if the province is to manage its groundwater resources well, a co-operative and well-informed approach is vital, to avoid unnecessarily large withdrawals, and other ill-planned pressures on supplies.

Muriel Stringer is a freelance writer living in Edmonton.

Muriel Stringer

The Quality Question

Contamination is hard to detect — and sometimes impossible to clean up.

With many small municipalities — and individuals — in the province dependent on groundwater for their supplies, the question is more than just one of quantity and the assurance of a continuing flow. When it comes to human consumption, quality is also a key factor in assessing the adequacy of a water source.

Although Canadian standards demand that drinking water should have at a maximum 500 parts per million of total dissolved solids, the domestic water supply in some communities, notably in northern Alberta, has 1,500 parts per million or more. In general, however, the public seems to be fairly tolerant of water quality which is less than optimal. Mary Gordon, a research officer with the Environment Council of Alberta, found that "people look on water quality as something that can't be helped — something you just have to live with."

Groundwater quality, explains Gordon Gabert, acting head of the Alberta Research Council's groundwater department, varies a good deal from one part of the province to another.

"Essentially, you have two kinds of aquifers as far as water quality is concerned. In the northern half of Alberta, you get predominantly unconsolidated aquifers such as sands and gravels. Here, the water is quite hard and has a lot of iron but it doesn't have as high a level of total dissolved solids as water from aquifers in the southern parts of the province. Down there, you have consolidated aquifers, with the water held in bedrock materials such as sandstones, shales, and coalbeds. The groundwater in this case is softer and has little or no iron but its dissolved mineral content is higher."

Most of the dissolved chemical constituents are calcium, magnesium, sodium, potassium, carbonates, bicarbonates, sulphates, and chlorides.

"The main undesirable component in bedrock aquifers is sodium," says Gabert. "Sodium sulphate, commonly called Glauber's salt, is a major inclusion, and so is magnesium sulphate, or Epsom salts."

Tim Bolec

While he notes that there are means for removing iron and unwanted salts from well water supplies, he adds that the depth to which the well is drilled may have a major effect on the quality of the water it provides.

"In the plains area of Alberta, you'll generally find that the deeper the well goes, the higher the dissolved salt content of the water. A shallow well would be less than 30 metres deep, a moderately deep one from 30 to 75, and a deep one 75 to 150 metres. You don't get very many deep wells, though — only about two per cent of all the wells in the United States, for instance, are deeper than 150 metres."

Iron and other minerals, however undesirable, may be considered as natural inclusions in the groundwater. There are, however, many other items which may be introduced as a result of man's activities. They may be both difficult to detect and almost impossible to remove by artificial means, such as the filtration and chemical processes used to remove iron and salts.

One of the more frequently reported sources of groundwater contamination is leaky or malfunctioning septic tanks and cesspools. With millions of litres of wastewater being discharged every year to such systems, waste disposal is a major potential polluter of underground water supplies.

"One of the difficulties of individual sewage systems such as you have on acreages and farms is controlling all the things that can go wrong," points out Bob Rippon, a hydrogeologist with Alberta Environment's soils branch.

"If the system isn't properly sited, designed, constructed or maintained, contaminants may enter the groundwater."

Septic systems based on percolation depend on three natural processes for their effectiveness. Suspended solids are filtered as the wastewater passes through the soil. At the same time, undissolved solids cling to the soil particles, and throughout the process, bacteria act to decompose the waste.

"How well such a system works depends on a number of factors," Rippon explains. "The permeability of the soil and the depth to the water table are important. As a general guideline, if the effluent goes through the soil at a rate greater than an inch (2.54 centimetres) every two minutes, this is too fast. On the other hand, anything less than an inch every sixty minutes is too slow."

Sandy soils, for example, transmit waste water best but don't give good degradation of nutrient contaminants.

"With clay, you have a different kind of problem. Places like Sherwood Park and Grande Prairie have heavy clay soils which don't absorb waste water well."

Organic compounds, synthetic detergents, and chlorides are some of the chief contributions a faulty sewage system is likely to make to the groundwater. Even more important from the point of view of their effects on human health are nitrates and bacteria, and there have been cases in the area north of Bruderheim where livestock wastes have caused nitrate contamination of farm or "barn" wells.

The effects of such additions may not always be readily apparent, because contaminants are spread through a large amount of water. But Rippon says bluntly, "The best solution to pollution isn't dilution — it's prevention."

He emphasizes that the key elements in preventing groundwater contamination from individual sewage systems are the careful choice of site to begin with, and continuing maintenance.

"It's important to plan wastewater management on a long-term basis. Also, we should be looking into innovative alternatives, such as treatments which separate the 'black water' or human toilet wastes from the 'grey water' or sink wastes. Ninety per cent of the nitrates in sewage are from the black water."

But sewage isn't the ony type of human pollutant that can cause groundwater quality problems. Landfills, which accumulate a variety of wastes, can also leak or leach harmful materials into water supplies.

Improperly located landfills can cause contaminated groundwater (below)

Tim Belec

Bob Chandler

"Most landfills are small sites," says Graham Jordan of Alberta Environment's soils branch, "Just about every hamlet has one, and they tend to get a minimum of 'housekeeping'."

What comes out is very much a function of the main items added to a dump, and it is hard to control the dumping of products which could easily enter the groundwater. In general, organic compounds are common in the water seeping from a landfill but chlorides, sulphates and a variety of metal salts are also typically found.

It is, however, as difficult to monitor what comes out as what goes in and so far the possible effects on groundwater are not well known. Alberta Environment has recently hired a staff member to monitor water quality in the vicinity of larger landfills throughout the province. As well, Jordan feels that province's program of centralizing landfills should make both the monitoring and control of potential contaminants easier to cope with.

"Dealing with waste is something the public needs more education in. Putting support into constructing and maintaining sanitary landfills to serve a larger area should help in this respect."

Often, though, the householder, rather than looking to his own possible part in pollution, tends to turn to industry as a prime offender. And there are many ways in which industrial development can introduce unwanted material into the groundwater.

"There are instances of gasoline leaking into the groundwater," says Bob Chandler, an engineer with the soils branch. "In Markerville, a large amount got into the water from the tank of an old service station. Then there was a case in Sherwood Park where gas got into a basement where a sump pump was running and caused an explosion."

Jack McCracken

Detecting gasoline in a water supply may be fairly easy but tracking down the source can be difficult if, as in the Sherwood Park case, there are several tanks in the vicinity. And an even worse problem is the clean-up after the damage has been done.

"Service stations aren't required to replace their storage tanks at any specific intervals. How long they last depends on a number of factors. But once gas gets into something like clay, it's very difficult to get it out. Clearing this up is going to take a long time. It may be decades before an aquifer contaminated in this way can be used to supply water for human consumption again."

Spillage from refinery operations is another way in which oil products can enter the water, notes Jack McCracken, head of the soils branch.

"There was the case two or three years back when hydrocarbons from a refinery were getting into the water around Inglewood bird sanctuary. The company did a good job on cleaning up its operation though."

Rippon suggests that oil well blowouts are also a potential source of contamination which merits further study.

Gas of another kind — butane — requires particular type of storage which may lead to leakage into the groundwater of high concentrations of salt.

"In Fort Saskatchewan and at Hardisty, there are brine ponds that form part of the oil companies' butane storage process," explains Chandler. "The butane is stored in a cavern about 900 metres below the ground. Salt water is pumped in to push the butane out as it's needed. When the butane produced is pumped down into the cavern, the brine comes up and is kept in a pond on the surface. Some of these ponds are quite large — the one at Hardisty, for instance, covers about five hectares."

All of the brine ponds were built with liners made of compacted clay which is susceptible to damage.

"The clay weathers, and reacts in unexpected ways at high salt concentrations. So far, the leaks haven't been into aquifers that have caused people to complain but one pond has now been lined with a synthetic waterproof material and two more are being looked into. It's a big job, though, because all the brine has to be pumped down into the storage cavern and the pond allowed to dry out completely before you can even make a start on the actual lining job."

Other types of artificial pools, such as gypsum ponds attached to fertilizer plants, may also seep chemicals into the groundwater, and tailings ponds in the oils sands area are another possible source of contamination which should be closely watched.

The Suncor Tar Island pond on the floodplain of the Athabasca River is in a "sensitive spot," says Tai Yoon of Alberta Environment's earth sciences division. The tailings pond attached to the Syncrude operation, however, is about two kilometres from the river and less vulnerable to factors which

Leaks from service station gas tanks are a source of groundwater contamination (below, and on Page 21)

HMH! CAN'T TELL IF THIS IS OILY WATER OR WATERY OIL!

might cause leakage to affect the groundwater.

Tai Yoon explains that Alberta Environment and Syncrude are co-operating in monitoring possible seepage through the geological formations beneath the pond. But results won't be available for some time because groundwater movement is slow.

Suncor is monitoring its own pond for seepage effects and is making its results available to Alberta Environment.

Other aspects of oils sands operations should also be carefully observed for possible effects on aquifers. Depressurizing basal aquifers below the oil sand to allow surface mining to go on can bring to the surface large quantities of water with a high concentration of total dissolved solids.

Wastewater ponds beside the bitumen extraction plants themselves are a third possible source of contaminants from oil sand activities. As well, the stock piles of sulphur and coke produced as by-products of the process represent another potential hazard.

"Materials leaching from these piles could get into the groundwater and cause problems," warns Tai Yoon.

Tapping of heavy oil sources adds to the possibilities for water contamination. "Produced" water, or water brought out of the ground along with oil, is high in total dissolved solids and hydrocarbons and may affect the subsurface water in a more dramatic way.

"This water has to be reinjected into the ground under pressure. It's possible that the pressure may cause the produced water to break through into shallow aquifers which are being used for domestic purposes. There's no evidence yet that this has taken place but it is a concern to keep in mind."

Then, too, tertiary recovery of oil entails the introduction of material below the soil surface that could pollute the groundwater supply. In order to produce more oil, water and often chemicals may be pumped down to the pay zones and could be pushed or leak through to an aquifer supplying domestic needs.

Coal seams, themselves excellent aquifers, are becoming a more important energy source with the threat of dwindling oil supplies. And coal mining and processing may affect groundwater in undesirable ways, suggests Tai Yoon.

"Drilling exploratory holes can bring to the surface water high in total dissolved solids. Then there's hydraulic mining, where water under high pressure is used to blast out the coal underground. They've been using this process for a number of years in British Columbia and it's just starting to get into Alberta. We should benefit quite a lot from the experience our neighbors have had but it's an area we have to be very careful about."

The four coal processing plants in Alberta, he adds, have settling ponds, and, although there are no instances of such ponds leaking into the groundwater, he believes they should be viewed as a potential source of contamination.

Clearly, groundwater quality can be adversely affected in many ways. It's important to remember, says Graham Jordan, that these effects will also be reflected in surface water supplies.

Tracing the origin of a pollutant may be extremely difficult and returning the aquifer to its original state may be prohibitively expensive or impossible in the short term.

As Jordan puts it, "You might well have to just stop using a contaminated aquifer. About all you might be able to do is let it clean itself up. And that could take hundreds of years."

Susan Mayse

The flow of groundwater is unseen, but there are

Signs On The Surface

Storm Creek springs

Groundwater has always flowed unseen beneath the earth's surface, but not uncharted.

Long before rock samples, pumping tests, chemical analysis and other techniques of hydrogeological mapping, ancient peoples were able to spot underground water sources — with enough accuracy to drill water wells and excavate ore bodies to a depth of several kilometres.

Roman engineers evolved a complex theory of underground rivers connected with the oceans, to explain large springs and rivers. This accounted for the saltiness of some springs and the copious water flow of others. The theory was incorrect, yet the Romans learned enough hydrology to provide their cities with fresh water delivered from the mountains by aqueduct.

But much earlier, and far beyond Rome's frontiers, people located underground water by careful observation of geological and botanical phenomena associated with different aspects of groundwater flow systems.

"Principles and field manifestations of regional groundwater flow" is the topic of a series of lectures given across Europe by Dr. Jozsef Toth of the University of Alberta during May and June this year. Just before his departure he took time to explain some of these indicators of groundwater.

"There are a whole host of these phenomena," he says.

Groundwater moves underground from areas of recharge on high ground where moisture is added to the soil, to lower areas of discharge where moisture is released at the surface.

"Groundwater in its journey from recharge areas to discharge areas dissolves and deposits matter, it transports, it has an ability to lubricate the mineral grains, and it has an ability to change the pore pressures."

All these factors produce an important effect: surface conditions vary greatly between moisture-adding and moisture-releasing zones.

"The phenomena attributed to groundwater will be significantly different in the area of discharge from those in the area of recharge," says Toth.

Moisture enters the recharge area in the form of precipitation, but leaves it in three different forms: evaporation into the atmosphere, runoff as surface flow into streams and rivers, and infiltration into the earth as groundwater.

"If you take a patch on the land surface you will see that there's one proponent providing water to that patch, and three proponents taking water away from that patch."

In the discharge area, however, the balance is different. Evaporation and runoff operate in the same way — but groundwater, instead of being able to infiltrate, adds itself to the area's existing groundwater. Instead of one proponent adding moisture and three removing it, there are two suppliers (groundwater and precipitation) and two releasing factors.

"Which means that we end up with more water in the discharge area than in the recharge area," says Toth.

This is why water levels decrease in recharge areas.

"If I drill a well that deep the water level will rise say to the land surface. If I drill a deeper well, the water level will rise to a distance below the land surface. In a yet deeper well, the water level will still be deeper. Otherwise the water couldn't go down. The water moves always towards lower water levels."

In discharge areas, on the other hand, water levels increase. In a shallow well, water rises to the surface. In a deeper well, it rises higher than the surface.

"That condition means that the whole

Dryland salinity Montana

pore pressure is significantly different" between the two regions, Toth points out. Pore pressure is the pressure of water between the mineral grains of the rock.

Hydrological balance and pore pressure are not the only physical phenomena resulting from the flow of underground water from high to low ground. In addition, material transported by groundwater accumulates in discharge areas.

Toth summarizes, "Discharge areas are moister, pore pressures are higher, and transportable materials accumulate there."

And all this leads to the visibly different surface characteristics at various spots in a groundwater flow system. Among them are botanical indicators.

"Obviously a different type of vegetation can be expected in an area where the moisture supply is copious as opposed to the recharge area where the moisture supply is deficient. So for example in the recharge areas you will have plants that are referred to as zerophytes, that is drought-loving plants. There are whole hosts of these drought-loving plants — silver willows and sages. You will find primarily pine trees and birch trees, as opposed to the discharge area where you will find moisture-loving plants called phreatophytes — sedges, jonquils, willows, poplar, aspen, spruce, tamarack."

The discharge area, because of its greater water content, displays physical as well as vegetative signs of underlying groundwater.

"This is the area where you can expect most of the springs and seeps and artesian wells, which themselves already impart a particular aspect to the country. All your major springs will be here."

Pore pressure accounts for some of these phenomena, separating the rock grains if the pressure is great. Water also lubricates the grains it surrounds, coating them with a thin slippery film.

"When you combine this pore pressure with slippery grain surfaces, obviously you will make that surface quite vulnerable to erosion. Then just a little bit of rain or even a plow on a slope may start to wash the soil away. You start with small washouts and then deeper gullies, then a spring will develop, so the spring will add water to that gully and eventually take the soil away. Then you get a gully which, particularly when it encroaches on agricultural land, can do a lot of damage."

Erosion still casts a frightening shadow across the prairies, after the "dustbowl" 1930s which cost many farmers their homes and livelihood. But groundwater-related phenomena can take other, less dramatic forms.

"Before you reach that stage what can also happen is that soapholes develop, with nothing there but quick sand, or quick clay," after pore pressure and lubrication have combined to liquefy the soil.

"The prairies are covered with these mud-

Learning from springs . . .

Once upon a time, somewhere in Alberta, there was a fish rearing station.

Since 1938, the facility had made use of the water from a nearby spring.

Recently, plans were made to expand the facility, and much money was spent. But none of the money went into a study of the spring. The result? An improved and expanded fish rearing station — and not enough spring water to supply it.

This cautionary tale illustrates not only the importance of monitoring one's water source, but also the importance of springs as messengers of the groundwater flow systems they represent.

Alberta Research Council hydrogeologist Domique Borneuf has made a study of springs in the province, and has classified them by type. Among his subjects:

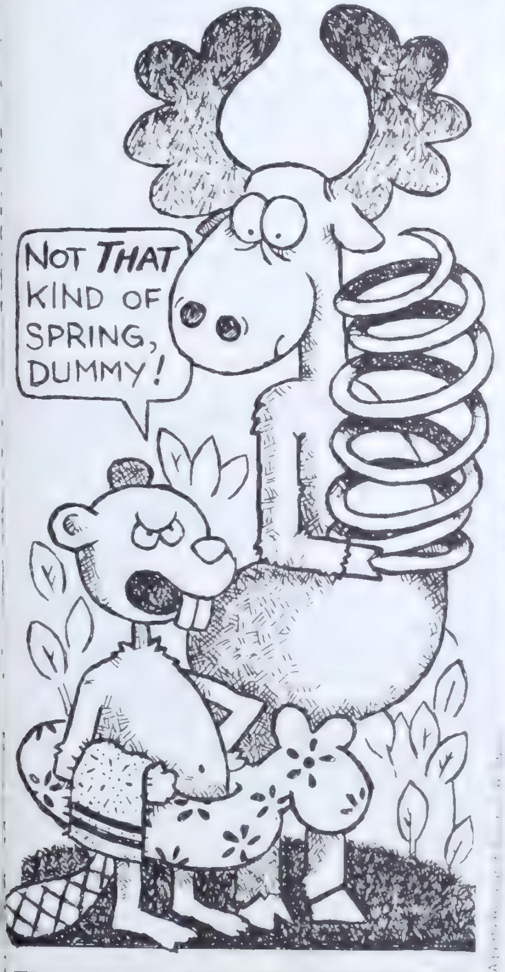
- Karst springs — like Big Springs near Mt. Castlegar in the Rockies. This group of springs discharges at the rate of some 60,000 litres per minute in summer, but dries up in the winter because its source is glacier water which freezes then. The Cadomin karst spring south of Hinton is similarly affected. Its discharge rate varies within a day, especially during spring and summer, when thawed snow and ice at higher elevations add to the flow.
- Butte springs, about 14 kilometres north of Caroline, five kilometres east of the Clearwater River. The elevation of the river is higher than the springs, and river water infiltrates through the alluvium and discharges at several points in large amounts. These springs have been monitored since 1971, and it's been established that it takes about 13 months for water to travel from the river to the springs.
- Hot springs, like those at Banff and Miette. The Miette spring temperature is about 52 degrees Celsius, that of Banff from 42 to 45 — but how deep the water has to travel to reach those temperatures is not known. Put simply, the water gets warmer the deeper it travels (about one degree celsius for every 33 metres). It then finds its way to the surface, through a fracture or set of fractures in the rock. But factors other than depth — like a mixing of colder groundwater from other sources on the way to the surface — can also be expected to affect temperature.

Brine springs and karst springs combine to produce this pool at the edge of a large salt flat. Wood Buffalo National Park (left)
Karst spring issuing from a cave in a gypsum formation Wood Buffalo National Park (below)

holes in discharge areas."

Another threat to agriculture production, salinization, is a concern less of the past than of present and future. Here also, groundwater plays a damaging role by transporting material through the soil from recharge to discharge zones.

"Much of this transported matter can be


NOT THAT KIND OF SPRING, DUMMY!

Ice stalagmites near the entrance of an ice cave in Wood Buffalo National Park (below)
Sink holes and coalescing sink holes Wood Buffalo National park (below right)

Alberta Research Council R. Stein

ions of various salts — such as sodium, magnesium, sulphate, carbonate, bicarbonate – which are transported in the water and brought to the land surface, where the water evaporates but the salts are left behind. Consequently, they accumulate in the soil or on the land surface."

This accumulation in the soil produces high salt levels, or salinity. Few agricultural species are tolerant of salty soil; an estimated 4.9 million hectares of farmland, mainly in southern Alberta, now suffer losses from salinization, some of which is groundwater-related.

"This is the basis of the alkali fields, of the salt-affected soils, which is an important agricultural problem. As a result you could have plants that are not only water-loving but also salt-tolerant — now you have a third group of plants, the halophytes. If you walk around in the prairies and see these bare patches with red short plants, salicornia rubra, that is a halophyte, and there are many others."

Susan Mayse is an Edmonton freelance writer

A spectacular variety . . .

Some of the most dramatic evidence of the ability of groundwater to alter surface and subsurface structure comes from karst formations.

A karst landscape (named for the characteristic Karst Region of Yugoslavia) shows irregularities in surface form caused by rock dissolution.

It's only now becoming generally known that Alberta has a fascinating and unique collection of karst features on its cold northern doorstep, in Wood Buffalo National Park.

"The geology of the area has been well known and investigated from the 1800s," says Alberta Research Council hydrogeologist Richard Stein.

"Looking at a geological map and seeing what outcrops, you would expect a set of groundwater features that would be somewhat different.

"But we had absolutely no idea of the number and spectacular variety of groundwater features that exist up there."

The revelation came in 1978, when Stein made a comprehensive survey as part of the research council's decade-long, province-wide hydrogeological mapping program.

He found springs discharging water 10 times saltier than sea water a few metres away from springs with a totally different water chemistry; springs discharging into, and forming sizeable lakes; springs discharging from deep holes in the bottoms of some lakes.

Of particular interest are a number of lakes and ponds produced by groundwater discharge which have bottoms lines with marl, a combination of clay and calcium carbonate. These lakes are a habitat preferred by the whooping crane.

Groundwater recharge in the area attracts scientific attention too. Stein considers most of the groundwater in the 14,000-square-kilometre study area to be local in origin —but points of entry range from broad high areas of fresh water with little or no apparent surface drainage, to deep sinkholes which swallow up the precipitation and move it rapidly through subterranean caverns.

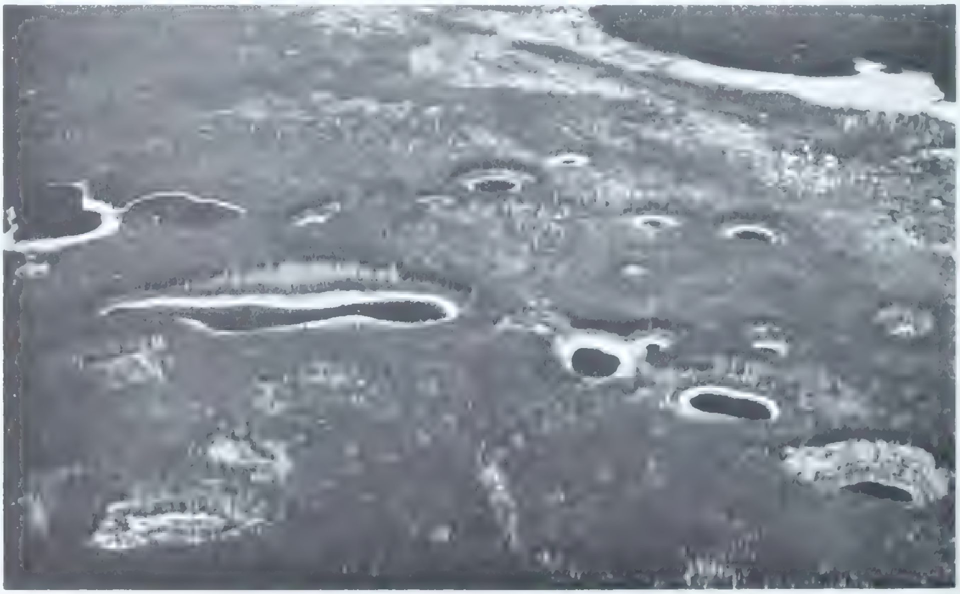
Geology probably accounts for all these differences.

In very general terms, the area is composed of a sequence of sedimentary rocks which lap on to the Canadian Shield. The sequence contains layers of carbonates (like limestone) and evaporites (like gypsum and common salt). The water moves laterally, dissolving elements of the rocks in its path. Its composition, and the way it discharges, is a function of the rock sequence through which it has travelled.

Many of these features are not accessible by road; many can only be reached – at great expense — by helicopter. So it's unlikely that the fragile ecology of the region will be destroyed by hordes of sightseers. Development of the gypsum deposits might be another story.

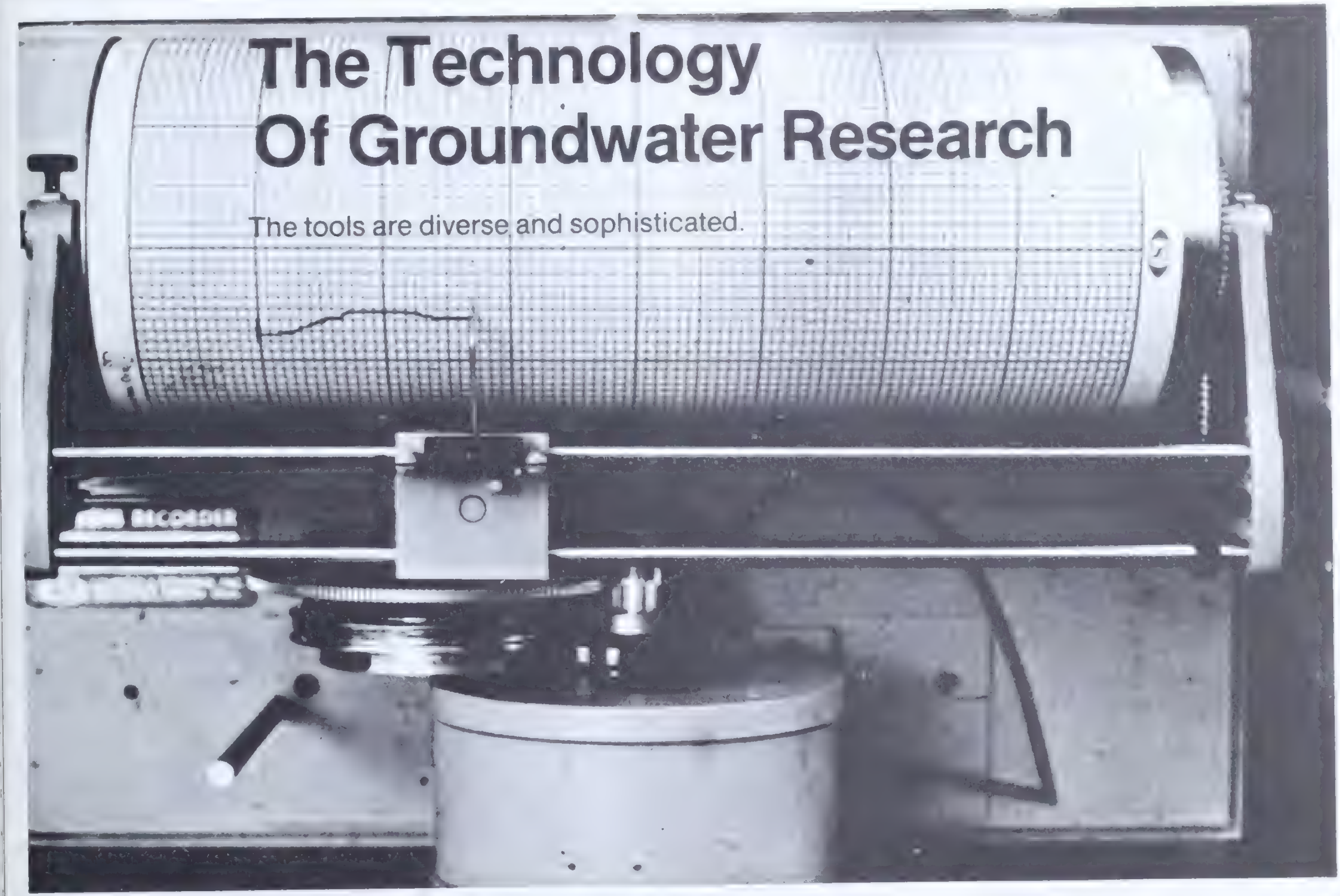
Stein considers the spectrum of features in the park to be of world scientific interest – and his photograph collection attests to their sometimes strange beauty. He sees a great need to preserve and protect them, and feels it is fortunate that they occur within the boundaries of a national park.

"We could learn a lot about the behavior of groundwater by monitoring and studying them."



The Technology Of Groundwater Research

The tools are diverse and sophisticated.



The solution to a hydrogeological mapping problem would ordinarily be expected to lie underfoot, not out in space.

But it was a space photograph that came to the aid of Dr. Gyorgy Ozoray, at work in 1967 in the Indian state of Tamil Nadu.

He needed a map to distinguish alluvial plains from the hydrogeologically different surrounding plateau in the delta of the Cauvery River. There were no suitable air photos, and topographical maps didn't show many relevant details. But color differences in the space photos delineated his project area clearly.

This was the first hydrogeological use of a space photograph; in the intervening years, satellite as well as the more conventional aerial photographs have made an important contribution to the study of groundwater.

And they are not the only examples of highly sophisticated technology applied to groundwater research.

The practice of aerospace surveys is called remote sensing. It makes use of not only visible light to produce conventional photographs, but also of infrared light and thermal imaging which give much more detailed information.

As well as identifying topographical and other surface features useful in the search for groundwater, remote sensing using thermal images tells the researcher about differences in surface ground temperatures.

For example, "cool" stretches on the photograph may mean wet soil or a discharge point for groundwater.

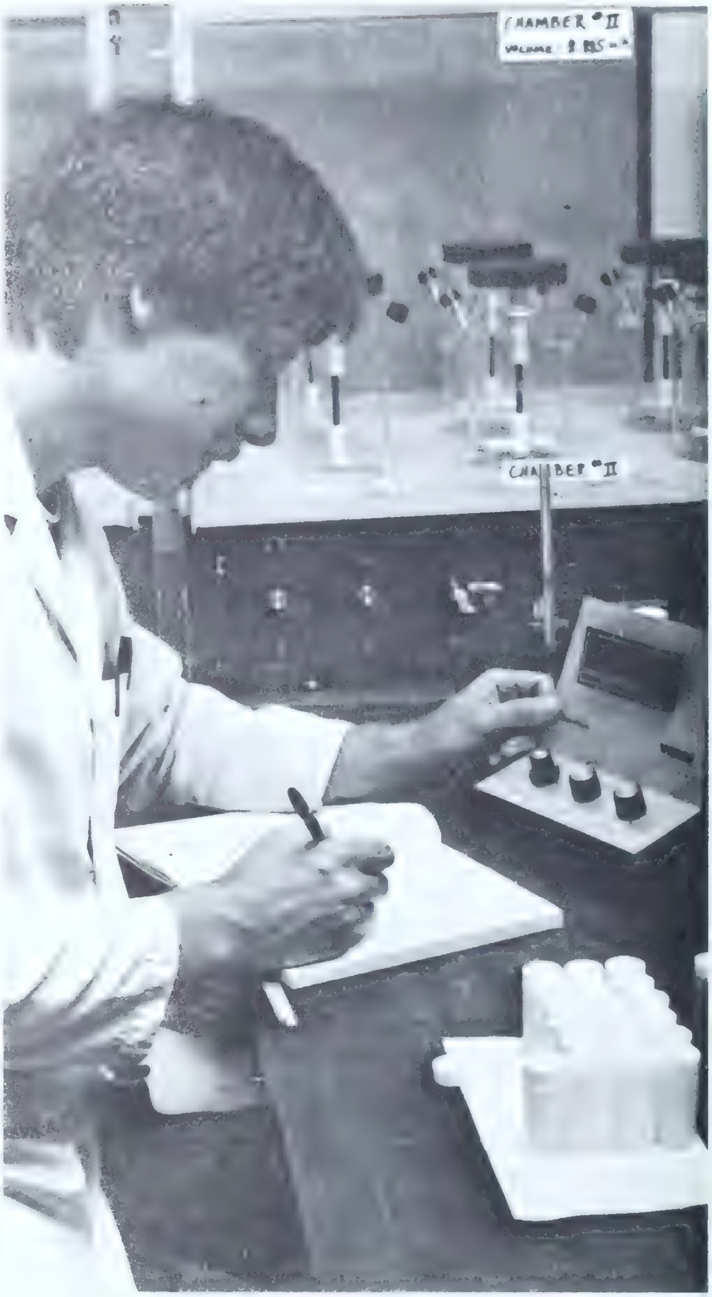
This sort of information may help solve a variety of scientific and practical water-related problems, including those concerned with mapping, surface analysis, geological analysis, land use planning, groundwater prospecting, and efficiency of water transport systems like canals and pipelines.

At St-Jean-Vianney, Quebec, there was a catastrophic landslide in 1971. Townspeople urgently needed to know whether the slide could extend further. Groundwater didn't pose a landslide threat, but in conjunction with other geological features, its presence may have been critical. A combined thermal, reflected infrared, visible light remote sensing and air photo survey was carried out to locate seepage zones, wet soils and other unstable places.

If remote sensing involves the study of groundwater from a considerable distance, isotope analysis is by contrast minutely detailed study of some of the elements of the water itself.

An isotope is one of two or more forms of a chemical element differing from each other in atomic weight and the composition of their nuclei, but not in their chemical properties.

Naturally occurring isotopes have been used since the early 1950s in the investigation of groundwater and surface water systems.



Those most commonly used are the radioactive isotopes tritium and carbon 14, and the non-radioactive isotopes oxygen 18 (cousin of the oxygen 16 present in the air we breathe) and deuterium.

Carbon 14 is the isotope used to establish the age of objects in the process known as carbon dating. With tritium, it serves the same function in groundwater research.

Oxygen 18 and deuterium are used mainly as indicators of groundwater source areas and as evaporation indicators in surface water bodies.

Their use stems from the fact that various isotopic forms of water have slightly different vapor pressures and freezing points, which in turn give rise to different concentrations of oxygen 18 and deuterium in different parts of the hydrologic cycle. The isotope content of water changes as a result of evaporation, condensation, freezing, melting, chemical reactions or biological processes. So isotope ratios at a particular point of groundwater flow give a researcher a good idea of the life history of the water.

In Alberta, isotope technology has been used, for example, to determine whether an aquifer is freely receiving water from the surface. If the deuterium-hydrogen ratio of the aquifer differs from that of recent precipitation, and if there is little or no tritium content, researchers can conclude that the aquifer was recharged during a different climatic regime. If there is no tritium, the water will be at least 50 years old. If there is also no carbon 14, it will be about 40,000 years old.

Computer modelling claims an honored position in groundwater technology in Alberta. Dr. Jozsef Toth, currently a groundwater specialist at the University of Alberta, is credited with developing some of its first principles here in the early '60s.

What is computer modelling? To attempt to describe it is to risk misrepresentation and oversimplification. But picture this:

Alberta Research Council water laboratory (Page 30)
Computer room used by the ARC groundwater department

computer models, using hard data, offer a conception of the natural situation under study.

Tom Corbett and Claude Sauveplane are both hydrogeologists. And they both utilize computer modelling technology in their groundwater studies at the Alberta Research Council's groundwater department. Both describe computer modelling as "one of the techniques to solve general groundwater flow theory." But it's a tool that is only as good as the information that is fed into it.

Basically, the computer model describes a natural situation. It is then up to the model-user to calibrate the model to bring it closer in line with the reality of the particular situation under study. Such parameters as the porosity and permeability of the underground strata and the geological boundaries of the study area are first determined. Then, one of the many available computer programs, offering a situation as close as possible to that under study, is chosen. The program is adjusted to represent the actual situation, and the necessary data is fed in.

The models give information on amount and flow of groundwater in specific formations. On a larger scale they can help establish the rate of recharge and the "safe yield" of aquifers in a region.

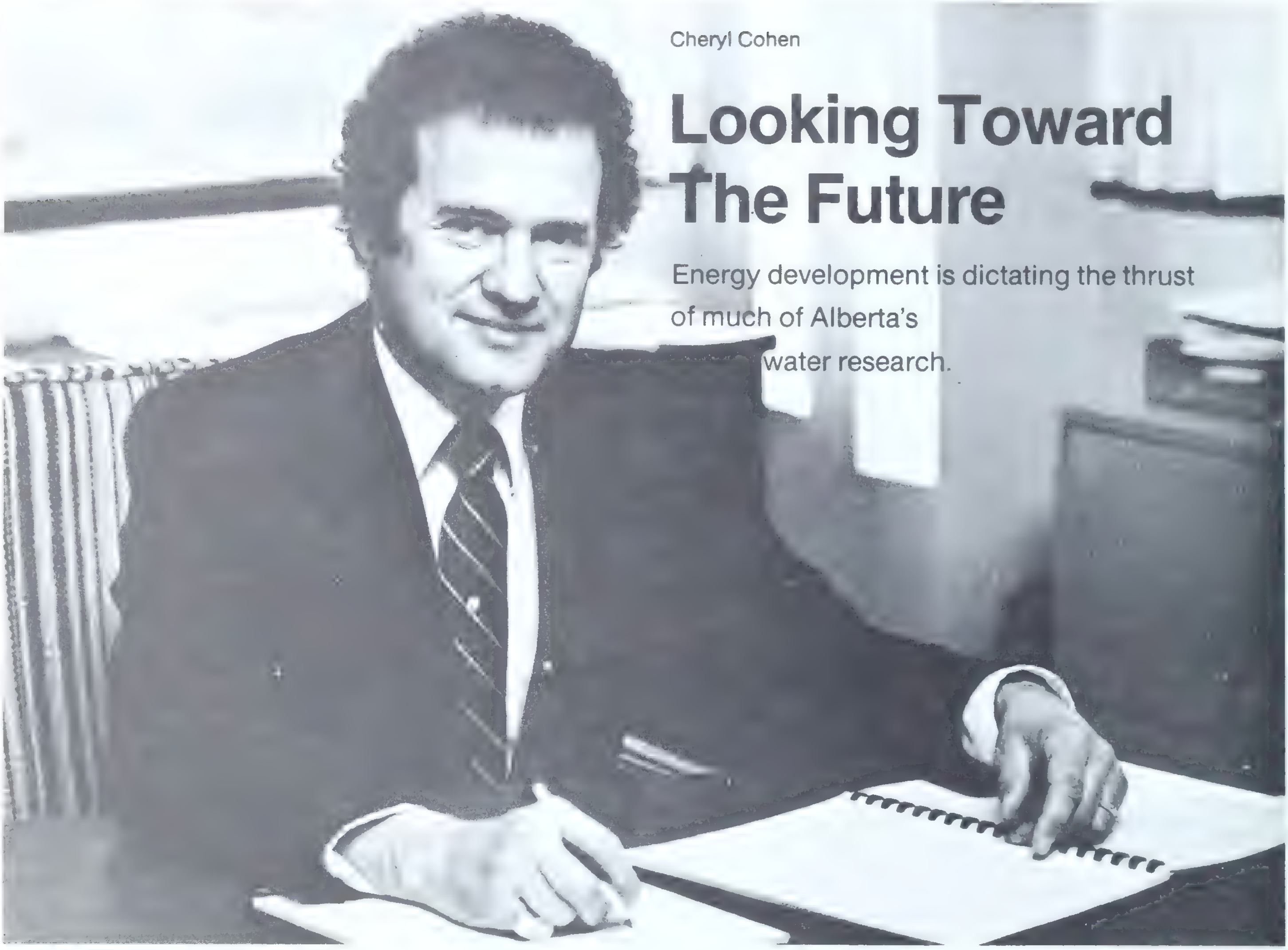
Sauveplane notes the value of using models for solving engineering problems such as dewatering of mines. They can also predict the productivity of wells operating simultaneously in a given aquifer.

There is application for agriculture too, in the use of models to study for instance the migration of fertilizers in groundwater, or means of improving the condition of salty soil.

Cheryl Cohen

Looking Toward The Future

Energy development is dictating the thrust of much of Alberta's water research.



Gordon Gabert

Groundwater has been around for eons, but it's only in the last century or so that scientists have been studying it carefully. In Canada, Alberta has established itself as a leader in groundwater research and today millions of dollars — public and private — are spent annually on in-province groundwater research projects.

Those doing the research include the Alberta Research Council, a provincial Crown agency which in 1957 established a groundwater department that acting department head Gordon Gabert recalls was the "only groundwater organization in Canada per se" at the time; Alberta Environment, which also keeps a regulatory eye on groundwater-related practices through the Water Resources Act and the Groundwater Development Act; universities; private companies; and individual consultants.

While scientists are quick to point out that groundwater research had already got a strong foothold in the province by the time the energy boom hit Alberta, they are equally quick to admit that much groundwater research being conducted now revolves around the energy industry.

"Groundwater research was very much in motion before we had the major thrust into oil sands and now, of course, coal . . . Groundwater has such an important influence on those areas I'd anticipate studies will be an important part of development — as well as giving a reasonable assurance of environmental protection," says Edmonton-based Gabert.

Alberta Research Council R Stein

One research project which could have an impact on energy development is the "world-class, frontier" research being conducted by University of Alberta professor Dr. J. Toth into the influence of groundwater on the flow of hydrocarbons. "This promises to be a major tool in oil exploration," says Gabert.

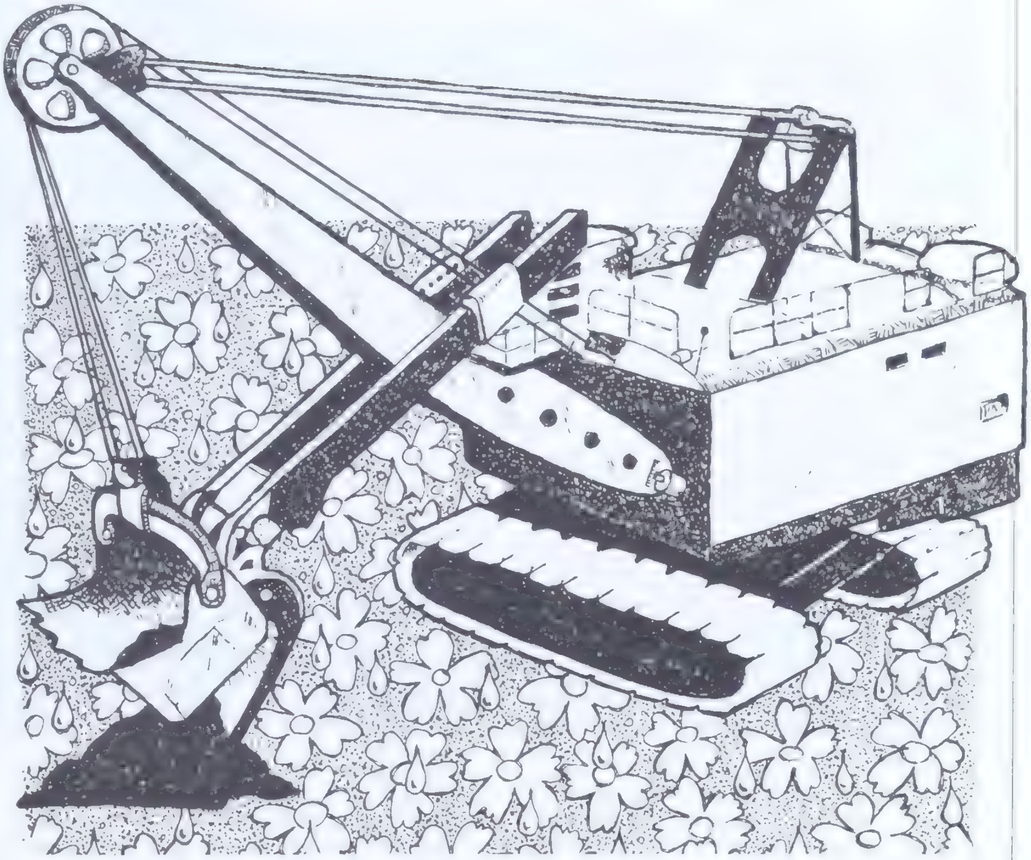
Petroleum, like other materials in suspension or solution, may be transported underground by means of groundwater flows, Toth suggests. World concern about fossil fuel shortages has exploded the theory into a global argument.

"It's reasonable to believe that many of the major oil fields of the world have been generated by this system," said Toth. "We're now fighting a worldwide battle about whether this is correct or not."

The idea behind Toth's work is that one can study groundwater flow in a large region and predict the most likely areas of potential accumulations of hydrocarbons.

But as Alberta's energy wealth is being tracked down, other researchers are taking a hard look at its actual or potential impact

Dragline at Diplomat Coal Mine, Forestburg



on the province's other major industry — agriculture — as well as on water supplies and the environment, through groundwater.

There's the five-year, $4-million-plus plains hydrology and reclamation project Dr. Stephen Moran of the research council is directing, for example.

"The principal concern we have is that, when you refill a (coal) mine site, in some cases water is significantly degraded," says Moran.

Short-term effects of coal-mining and reclamation have been looked into "very well" by mining companies and researchers alike. What he is concerned about is the long-term results of this activity within a 25- to 100-year time-frame. Moran is anxious to avoid leaving a legacy of "time bombs for our grandchildren."

His research is addressing the problems of how to predict what the quality of water in mine spoils will be and what the implications, if any, would be if the quality was poor.

"We're talking about a local problem," Moran stresses. "It would be restricted to the immediate vicinity." But a coal-mining operation may cover an area of 104 square kilometres and Moran says that, in a worst-case scenario, "we're looking at some portions of that area being affected to the point where there's significant salt-affected soil and problems in growing anything there . . . and no potable water available within the depth of the mine."

A spin-off of this research has been determining the options for water availability given the setting of certain mining areas.

In most areas of shallow coal, where there's surface mining, a "significant proportion" of wells for farm water supplies are completed in coal beds, Moran notes. Since mining removes the aquifer or water-bearing bed that the farmers' wells are exploiting, farmers need to get their water from another source.

At Battle River, east of Stettler, where Moran's research has been conducted for the past two years at two existing mine sites, the answer was to drill the wells 50 to 80 metres below the surface instead of 10 to 30 metres below, so that they are below the depth of the mines.

Farmers' wells not only have to move out of the way of coal-mining operations; they are also believed to be affected by shock waves from the seismic blasting operations associated with energy development.

Recently, in a joint groundwater research venture, the research council, Alberta Environment and Alberta Energy and Natural Resources have been trying to determine the effects of seismic blasting on farm wells. The results, says Allan Kerr, head of the groundwater branch of Alberta Environment's earth sciences division, could lead to

Alberta Research Council

Weathering phenomenon in mine spoil, photographed during hydrogeological investigations for reclamation of land disturbed by strip mining

more farmers getting compensation from the provincial government for water-well damage than has happened in the past.

Kerr says that it's been more or less accepted within the industry that, if a company blasts less than about 180 metres from a farmer's well, industry is held responsible (through Alberta Agriculture's water-well recovery program) for any damage claim laid by a farmer.

According to farmers' claims, seismic blasting can result in one of two things happening to farm wells, adds Tom Sneddon, of Alberta Environment's research management division: there may be a change in water production or the water quality may be affected — the water can turn cloudy. "Nobody's too sure why. Blasting mechanics are poorly understood."

Kerr's branch is also involved in research in the Cold Lake area on the effects of deep-well and steam injections on the countryside.

An "extensive" research project is under way to find out more about some minor earth tremors that have been noticed in the area — whether they are natural, or the result of military activities (perhaps sonic booms), or the steam injections used in oil recovery to make oil more fluid.

"These things are happening; with accelerating development there could be concern with groundwater contamination — for example, pipes may rupture — and we want to get a handle on it now," Kerr says.

Associated with this, he says, there is a lot of injection of waste water in the Cold Lake area. Under "quite stringent" controls, companies may not inject less than about 600 metres beneath the earth's surface, but researchers want to protect the groundwater and determine whether there is any danger in disposal at depth.

"It's never happened in Alberta, that we know of," Kerr says. But he notes that there have been instances in North America where the waste goes in at one spot and comes up in another spot.

The groundwater itself could be contaminated. In the research area, the groundwater goes down to about 150 metres, leaving a gap of several hundred metres before the injection depth. "We want to be sure there's no way the injection gets into shallower groundwater."

Researchers have other groundwater concerns in oil sands areas.

Aquifer flow specialist Claude Sauveplane of the research council notes the need for a clean job to be done. And since a lot of water is used in the process of extracting oil from sand, there is concern about the capacity of groundwater resources to meet development and production needs.

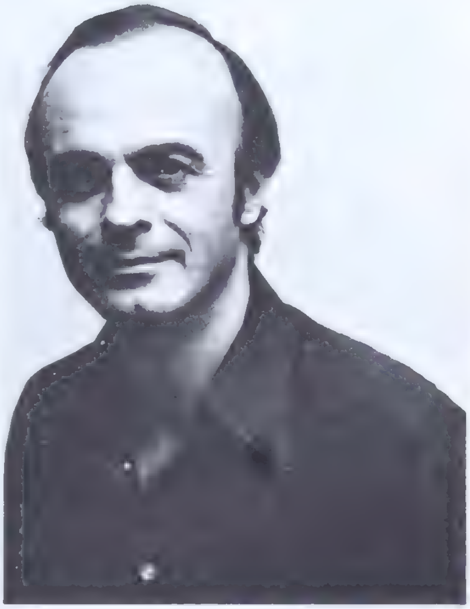
Sauveplane, who until a year ago was working for the French geologic survey, says research has still to determine what products — contaminants or otherwise — result from oil sands exploitation (there are "all kinds" of possible chemical interreactions underground, depending on the process being used) and whether these products are immediately absorbed by the soil or if they have a chance to move away from the area through groundwater flow.

Meanwhile, he is deeply involved in research aimed at finding methods of predicting how much water can be pumped from water-bearing formations in Alberta.

Ways of exploiting groundwater resources from geologically uniform areas have been well developed, he notes. But in Alberta, where the geology is very varied and complex in places, "it is often difficult to predict the lateral extension of aquifers" everywhere.

"The maximum and optimum use of water still needs more research. The province of Alberta is going to develop many activities with the energy wealth and it is easy to forecast that water requirements are going to be much higher than now. Surface water won't be the only suitable solution to cover all these developments.

In particular, Sauveplane adds, the future needs of agriculture must not be disregarded. Groundwater research, he says, has to take into account the long-term when the energy boom is slowing down.



Claude Sauveplane

Sauveplane says the groundwater research connected with coal gasification — the process whereby coal is gasified or liquefied because the deposit is too deep and therefore uneconomical for strip-mining — can reach a similar stage to that connected with the oil sands.

"But forecasting of this development is much more down the line than with oil sands." There have been experiments on coal gasification and some effects on groundwater in Alberta but, says Sauveplane, "if coal gasification is going to be developed in Alberta, it's not difficult to forecast we'll be much more active in that field."

Groundwater research pertaining directly to agriculture is being carried out in Alberta, too.

In one of these research projects, where groundwater shared the focus of attention with soil and crops, Dave Graveland, head of the technical development branch of Alberta Environment's earth sciences division, has been involved in a decade-long look at the environmental effects of waste-water irrigation.

After studying several municipal and industrial waste-water sites, he says the only significant effect of waste-water irrigation on groundwater was found to be that chloride levels tended to increase. But the amount levelled off and did not reach alarming or unacceptable levels.

Up to 30 Alberta towns use all their effluent for irrigation and, says Graveland after the research, "as far as we know, it's safe."

With feedlots, though, "I think we've proven groundwater can be contaminated." In studies of four or five intensive livestock operations, it was found that at feedlots groundwater contamination can occur, not through the feedlot floor itself, but when run-off water flows out of the feedlot on to non-compacted soil and then enters the ground.

The solution was to collect the run-off in a special pit — but there is no legislation in Alberta requiring such containment.

In another area of waste-connected groundwater research, Gene Leskiw, solid-waste engineer in Alberta Environment's pollution control division, says his department has conducted a number of small projects involving monitoring to see whether there is groundwater pollution from sanitary landfills.

Groundwater contamination is a major research concern with sanitary landfills, says Leskiw.

"In places, the contaminants may travel quite rapidly — 30 to 40 metres a year; in others, a few centimetres a year — or in 10 years."

Organic and inorganic pollutants can get into the groundwater through leaching and end up in the water supply.

"The biggest concern is the pollution of a resource," Leskiw says. "In many instances, people don't stop to think of how big a resource it (groundwater) is. There are a lot of areas in the province handicapped by the availability and quality of the resource."

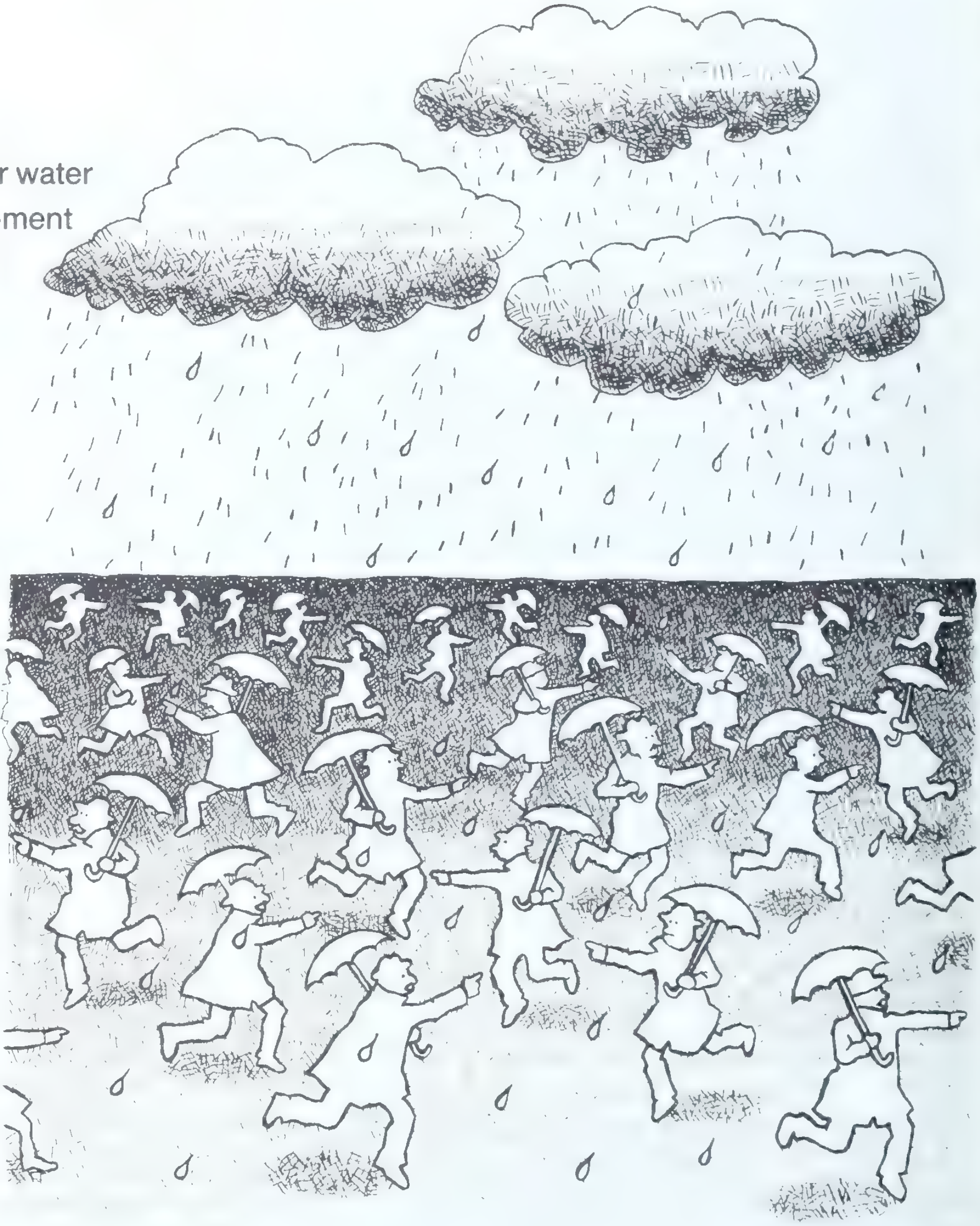
It's a point made often by people connected with groundwater research in Alberta.

Cheryl Cohen is a journalist in Calgary

Susan Mayse

The International Scene

Money, experience and the need for water affect rates of groundwater development and levels of research.



Groundwater has been known for ten thousand years, yet not always understood.

Centuries ago, farmers worshipped springs and underground streams as gods. Water for crops, livestock, small industries — surely such generosity from the earth was divine. In early China, Iran and India 1,500-metre wells and kilometres-long tunnels tapped deep unseen water bodies and produced up to 63 litres a second of sweet or salty water.

Today, hydrogeologists not only understand the principles of groundwater but have discovered complex methods of assessing the amount, quality, location and underground movement patterns of groundwater. Regions around the world have developed at different rates, however. This is reflected in the use of groundwater resources in old developed areas, in third-world nations, and in post-colonial countries.

Groundwater, though an essential resource, has been overlooked in some areas, says Dr. Jozsef Toth, who works with the University of Alberta's departments of geology, engineering and physics. Not as visible as surface water, groundwater is also more costly and technology-intensive to exploit than surface water.

Western Europe and the Soviet Union set the standard in most aspects of groundwater development, says Toth. Even small countries use highly sophisticated methods of monitoring groundwater availability.

"They systematically map and keep mapping their countries, and they set up groundwater management units which are managed just like a bank account. They keep track of every drop of water entering that unit — precipitation, inflow through rivers and lakes, and through groundwater — and then they measure the total consumption."

Both human and natural "withdrawals" are under observation through a dense monitoring network of all components of the water balance, producing a running "bank balance" of water supplies.

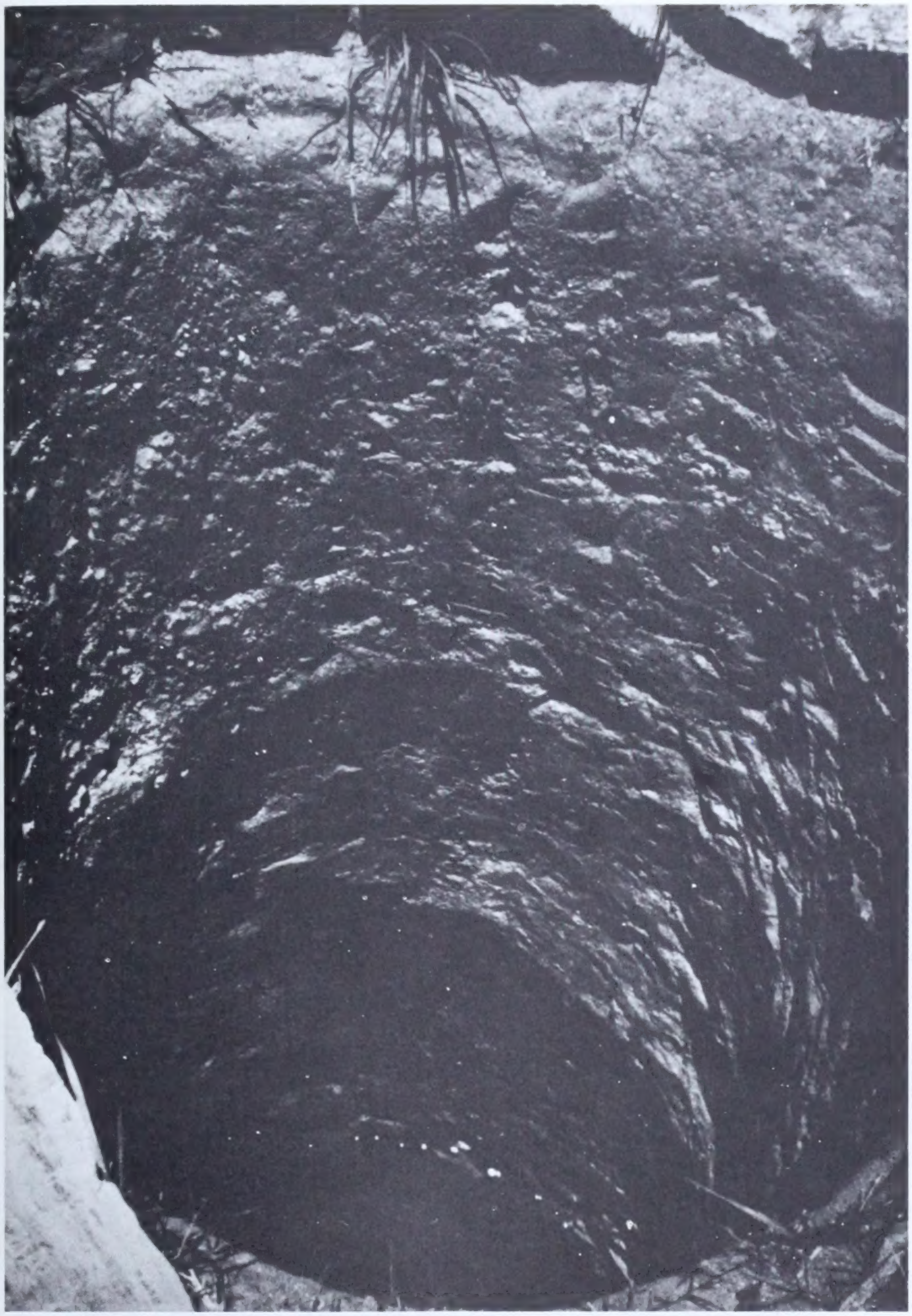
France is one of the most advanced developed nations in terms of groundwater technology. Like other European countries, complex agencies and services are at work in the field of groundwater — hydrogeological centres, university departments, government institutions to concentrate on survey, mapping, evaluation, exploration and exploitation, and central data banks.

"The strongest and central hydrogeological group in France is what would be the French equivalent of the Canadian Geological Survey, BRGM —Bureau de Recherche Geologique et Miniere. Hydrogeology is just one of their aspects because they look after ore exploration, coal, gas, petroleum and other things. In addition to BRGM, major municipalities have their own groundwater survey and groundwater development groups, so it's not the BRGM that's doing the work all over France — the local municipalities or departements, the equivalent of our counties, have also their groundwater-oriented groups."

BRGM, however, supplies the basic data and serves as the central depository of all groundwater-related information.

"Our research council is the central depository on a much smaller scale," says Toth.

Groundwater is extremely important to some areas of France. The city of Bordeaux, for example, draws its entire industrial and domestic water supply from beneath the earth's surface. This would not be possible everywhere, depending on the geology of the region, but by the same token would not be necessary in some areas. French farmers, like most European farmers, "rely on groundwater because of the obvious difficulties of



India: bored well

supplying farms with piped water."

Farmers pay no special charges for the use of groundwater. "Unlike in Alberta the mineral rights are vested in most Western European countries in the land ownership, so that if you own the land you have the mineral rights too, and groundwater is considered as a mineral resource."

French wines are proverbial for both their excellence and their heavy domestic consumption. Even the fermented grape provides an unorthodox indicator of groundwater supplies, Toth says with a smile.

"Where the groundwater is not good, they drink wine. Wine-drinking is inversely proportional to availability of good groundwater."

France's groundwater activities extend far beyond the French borders. Foreign as well as domestic contract work takes BRGM expertise as far afield as Asia, South America and the Middle East, although Africa —with its many former French colonies — remains the major area of interest.

Constantly increasing demands for safe and copious water supplies has led to groundwater awareness in third-world countries. Undeveloped countries such as Uganda and the Congo show only rudimentary groundwater exploitation, but developed third-world countries are making huge strides forward, usually with aid from more highly industrialized nations.

"Third world countries have a few good theoreticians, but groundwater is a costly proposition and they don't have the money.

"I think that India recognizes more than any other third world country the importance of groundwater supply. They have a very strong Central Groundwater Board — it's part of the department of agriculture."

Toth, who has worked closely with several branches of the Central Groundwater Board, commends the service's well-reasoned approach to an enormous need for water.

"They have already produced the hydrogeological map of India and they are instrumental in producing the groundwater map of Southeast Asia. They pride themselves on being very good theoreticians, which they are. Their problem is lack of equipment, lack of organization, and of course finances."

Many thousands of people are employed in the Indian board's dozen or so districts, all of which are active in exploring and developing groundwater. India planned early to establish its "green revolution" substantially on groundwater supplies, relying heavily on it for irrigation in the dry interior regions of the subcontinent. Tropical areas such as Bengal and Tamil Nadu, on the other hand, suffer a surfeit of surface water.

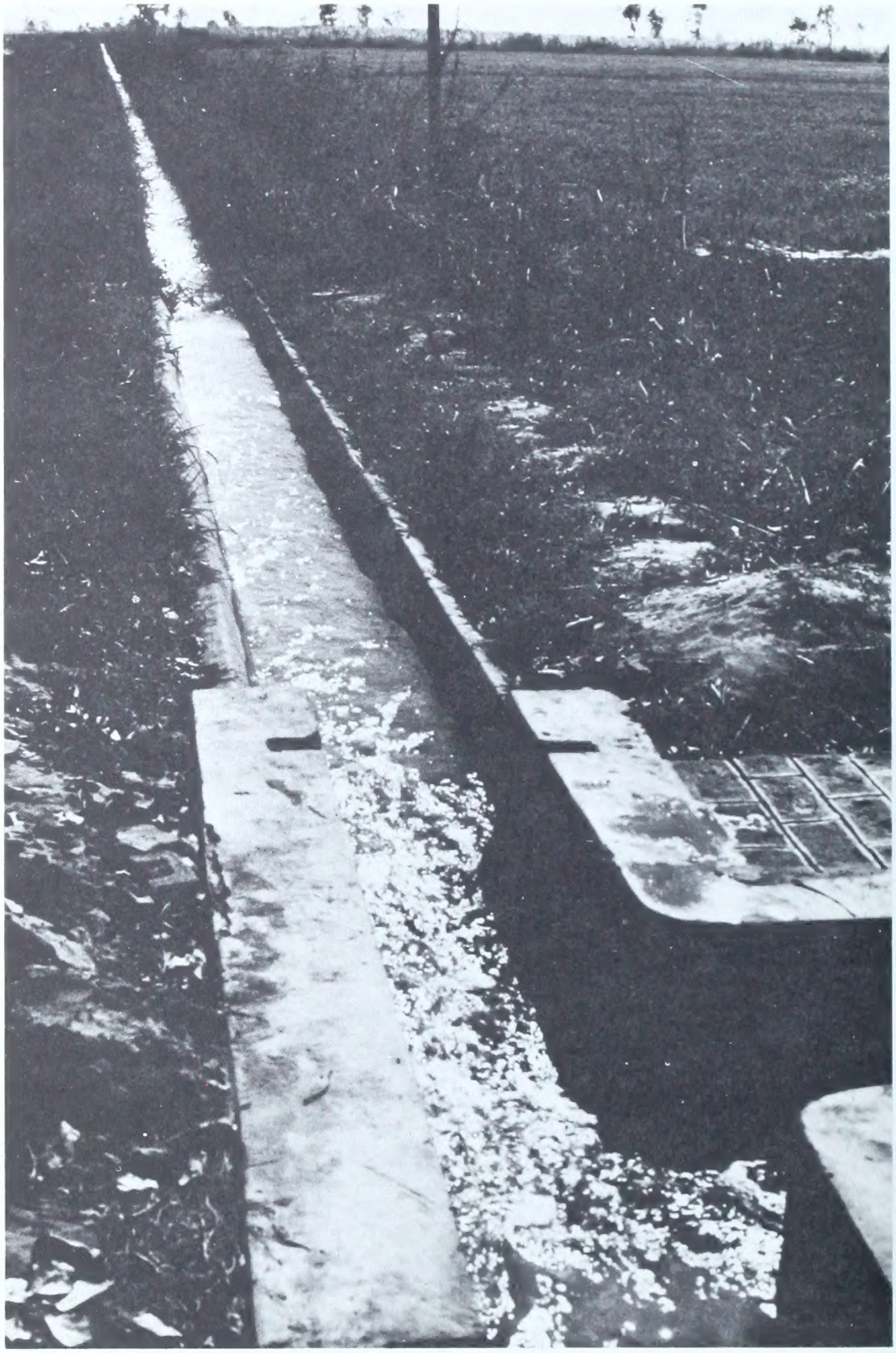
"Sometimes they have the curse of too much of the good."

Tamil Nadu's Neyveli Lignite Fields are a case in point. The open pit brown-coal mine and thermal plant are somewhat similar to the Athabasca Oil Sands.

"The problem with the mine itself is that it is underlain by highly-pressured artesian water," says Toth. "As they dig and remove the overburden and then the coal, then the water breaks up the floor and the water rushes in and hampers operations. In order to prevent that from happening they have to drill large numbers of very high-capacity wells around the mining pit. It requires a tremendous amount of pumping, and of course the problem is, what do you do with the water?"

Pollution is a constant hazard from the mine's runoff into local streams, and the expensive dewatering process gives the international project only borderline profits. "But the investment is so huge that no one can really give it up. It is the focal point of that

India: irrigation canal carrying water from a flowing well to rice and sugar cane fields (right)



region's economy."

Sheer size, in the last analysis, is usually the problem in India.

"When you have to supply 600 million people, starting from a very poor economic situation with completely inadequate facilities, you have such a problem on hand that I for one do not see a solution to it. The few feasible solutions that there would be, one just doesn't want to talk about. You can't start reducing populations by any human means. Birth control and so on — they are valiant attempts, but again, unmanageable. It's a vicious circle.

"I've seen groundwater work locally in improving the situations of places in the east — Andhra Pradesh, and the Krishna Bodhivari — where beautiful orange groves and market gardens and cash crops are grown on the strength of groundwater. There it works. The investment paid off. But that's just a drop in the bucket.

"I think that individuals or agencies, national or international, are fooling themselves if they think that they can significantly improve the situation groundwater-wise or otherwise. It's by no means that they don't have the potential to do it — it's that the size of the problem is so immense."

Australia, in groundwater terms, is fairly typical of developed former colonies. Toth compares its situation to Canada's own.

"It's quite sophisticated, just a few men pushing for regional and then overall comprehensive groundwater evaluations but not having enough sympathy and understanding to be able to carry it through. When they need some highly-sophisticated and large-scale evaluation, then they have to resort to foreigners."

France's BRGM was responsible for a major five-year survey and assessment of Australia's huge groundwater reserve, the Great Artesian Basin, one of the largest such resources in the world.

The Great Artesian Basin occupies more than 20 per cent of the Australian continent, and is confined in a vast bed of sandstones, mudstone and siltstone laid down in the Cretaceous age and earlier. Located in the north-east section of Australia, the Basin mainly underlies low interior plains and is bounded east and west by higher ground. Layer upon layer of aquifers, or water-bearing zones, make up the ancient subterranean water body. In places, it's three kilometres thick. Australia's expansion has depended heavily on the Basin's reserves, with stock-raising operations and towns relying largely on artesian groundwater.

Australia's main agricultural development, nevertheless, was based more on surface water. As a result, groundwater availability was not mapped or assessed early, and few hydrogeologists work in the country.

Toth notes a point of similarity with North America: "They lack expertise."

"But they are preparing themselves. I don't know much about Western Australia, but the Sydney and Canberra regions have sufficient surface water but still a fair amount of groundwater supply."

Lack of trained groundwater specialists is endemic, Toth admits, especially in countries such as Canada which relied on surface water for their original settlement and industry.

"That might be a characteristic of a developed colonial country, that we don't have enough expertise — and certainly we don't have enough home-grown expertise."

Groundwater theory is a strong point in

India: flow from a 150-metre well in the foreplains of the Himalayas.

North America, with highly-developed techniques for measuring the water-bearing and transmitting capabilities of rock formations. Practical aspects like mapping, and overall assessment of regional water availability, lag behind.

"I think it's historical. I think that North America in general and certainly the prairie provinces are so much younger than the eastern or western coastal regions of North America or Western Europe — the demand on groundwater is so much less than in Europe where they have to account for every drop of water that enters — that there was no need for us as yet to be that accurate and refined with our overall evaluation.

"We are not doing it yet because we haven't been forced. We are entering this stage now. We have such a golden opportunity because we know how to do things, we've seen examples in other places in the world, we are not forced to resort to emergency solutions — so that we have the time to get ready and prepare ourselves for the time when we will have to do the same thing as the more highly developed countries."

Canada and the United States now face problems in the practical, rather than the theoretical, aspects of groundwater development, says Toth.

"We find ourselves in a vacuum. We have grown faster than we have supplied groundwater-oriented people. Now all of a sudden we wake up that we need all of these people, and we don't have them. The schools are not equipped, there are prejudices that have to be overcome. When you propose a chair or a position at a university in hydrogeology, then colleagues are not sympathetic — they don't understand, because they haven't seen the need. There is always a certain amount of inertia between realizing the need and being willing to try to satisfy it."

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Environment Views
Alberta Environment
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Environment Update

Milfoil Campaign Mounted

Eurasian milfoil is a fast-growing weed that clogs lakes. It is currently the scourge of Lake Okanagan.

It is also extremely hardy — a fact which has Alberta Environment officials worried. It spreads most rapidly by fragmentation, and fragments can survive out of the water for up to three weeks if they are in a damp place.

The department is planning a public awareness campaign aimed at preventing the spread of the weed from British Columbia. Vacationers are urged to clean off their boats, outboard motors, water skis and other water-based equipment, to avoid transporting weed fragments to Alberta lakes.

HI THERE! I'VE ALWAYS WANTED TO TRAVEL ALBERTA!
MILLY FOIL B.C.

Conference Stresses 'Human Side'

The impact of resource developments on communities will be the subject of the second International Forum on the Human Side of Energy, to be held at the University of Alberta August 16-19.

Topics for discussion will include the impact of energy development on social institutions and on vulnerable groups; social, psychological and cultural impacts; planning and policy issues; and energy and the future.

Designed for community residents, educators, and representatives of government and industry, the format will range from keynote address and formal papers to panel discussions, workshops, community presentations, informal dialogue, community theatre and field trips.

The aim is to pool and share information and resources, so that decision-making, planning and management processes involved with resource development can be improved.

'Energy Bus' Running

The federal government's "Energy Bus" is now on the road in Alberta.

Described as an energy conservation program on wheels, the bus offers free advice on energy use to businesses. Information about energy consumption in factories and offices is fed into the bus's mini-computer. A print-out suggests ways to conserve energy and estimates cost savings if conservation measures are taken.

This "energy audit" is also available to public institutions such as schools, as well as to businesses.

Land Access Threat Seen

The Alberta Wilderness Association is mounting a campaign against what it claims is a threat to right of access to public lands.

That threat is contained in the newly revised conservation and hunter education manual, which states that hunters on grazing leases without the permission of the lessee are guilty of trespass.

The AWA maintains that Crown lands under grazing leases are public lands which should be open to all.

Containers Collected

Alberta Environment's pesticide container collection program will be running again this summer. Rural users of pesticides are urged to triple-rinse and puncture their containers, and take them to special disposal sites in their area.

More Studies On Mercury

Studies preceding construction of the proposed Slave River power dam in northern Alberta have found indications of mercury in the area.

But Dr. Martin Swales, in charge of feasibility studies for the dam project, says that subsequent investigation has shown that the mercury occurs naturally, and that there is no evidence of bioaccumulation.

However, since impounding water has been found to increase the concentration of heavy metals, including mercury, further studies will be undertaken.

If you have a short news item of province-wide interest you'd like to contribute to Environment Update, please send it to the editor at the address on the Contents page. The editor reserves the right to select and edit the items.